Belcan

NATIONAL RENEWABLE ENERGY LABORATORY
Golden, Colorado
ACI-4-14235-01

Technical Monitor
Brian Duff

Final Report

for

Screening Study for Sawmill Waste Biomass-to-Ethanol Production Facility

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prepared by:

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1.0
PREFACE

1.0 Preface

The DOE and NREL contracted with Belcan Engineering Group, Inc. to perform a screening study to investigate the technical and economic feasibility of processing cellulose into ethanol at a large scale biomass-to-ethanol (BTE) facility. This project is part of the effort by DOE and NREL to convert environmentally troublesome ligno-cellulosic wastes, currently a burden to local and regional hardwood sawmills and businesses, into transportation fuels, thereby strengthening the economy in multiple ways. In line with this effort, the scope of the project was defined to include the "identification and evaluation of a site or sites in the Kentucky, West Virginia, and Ohio area which would be appropriate for long-term operation of a financially attractive sawmill waste BTE facility". To this end, Belcan selected two sites for the BTE process (Task 1), estimated the costs of construction and operation (Task 2), developed business pro formas for evaluating economic viability or soliciting business investors (Task 3), and outlined a schedule for construction, additional testing, and startup (Task 4). To accomplish this, Belcan performed the following sequential subtasks according to contract # ACI-4-14235-01:

- Estimated the quantities of hardwood sawdust that would be available at reasonable prices for the production of fuel grade ethanol. [Task 1]
- Identified the size, production capability and minimum facility requirements for a plant processing these estimated quantities. [Task 1]
- Determined the equipment, capital costs and operating costs involved in processing this sawdust at a generic "greenfield" site. [Task 1]
- Screened the tri-state area for potential sites for the construction of a full size commercial facility. [Task 1]
- Identified the key environmental and community issues impacting the screened sites, evaluating these factors, along with economic information, to select eleven possible greenfield sites in the tri-state area. [Task 1]
- Ranked the potential greenfield locations according to economic, environmental, community and engineering siting factors. [Task 1]
- Refined the generic greenfield cost estimate to be consistent with construction of a full sized commercial plant at the highest ranked location. [Task 2]
- Estimated capital and operating costs for installation of the BTE process at an existing ethanol production facility (SPE) and construction of an interim sized engineering demonstration unit (EDU). [Task 2]
- Prepared financial pro formas detailing the economic viability of the BTE process based on analysis of fuel grade ethanol prices, fuel costs, financial data, and capital & operating costs. [Task 3]
- Solicited potential business interests from the alcohol or ethanol manufacturing industry, as well as contacts in the sawmill industry that would benefit from having a profit making sawdust "disposal" facility. [Task 3]
- Identified the technical and financial issues that may require evaluation to further establish manufacturing capabilities and/or attract potential investors. [Task 4]
- Developed a master schedule which included investigation of technical issues at the existing pilot plant unit (PDU) and interim engineering demonstration unit (EDU), detailing the time frame for subsequent design, construction and startup of a full scale commercial facility at the SPE or greenfield location. [Task 4]

The body of this report is represented by an executive summary and four sections describing the results from the performance of each of these four major tasks. Each section incorporates updated technical information and comments made by NREL personnel on preliminary reports submitted for each of the tasks or subtasks. Each of the four sections highlights the revisions that were made to the preliminary report, and summarizes the final results. These final results are condensed further in the executive summary which follows this preface.

Several people are acknowledged as having contributed significantly to the writing and the review of this Final Report. Those people are Mike Arnold, Philip Beirne, Chris Brown, Charles Easley, John Slomba Bryan Speicher and Fred Strauss. Bryan Speicher is the Project Manager.

2.0
SUMMARY

2.0 Summary

Based on the Biomass-To-Ethanol (BTE) process described in the 1991 SERI Technical Report "Technical and Economic Analysis of an Enzymatic Hydrolysis Based Ethanol Plant", a determination of the minimum facility requirements for a hardwood sawdust BTE facility was made. The study began with an analysis of the primary raw material sources or hardwood sawmill locations. Information was collected from the United States Department of Agriculture, Ohio, Kentucky, and West Virginia Forestry Associations which identified the tristate and the surrounding area as the principal region for hardwood sawmills. An estimated 1,200,000 tons of hardwood sawdust is generated in Ohio (250,000 tons), Kentucky (500,000 tons) and West Virginia (450,000 tons) each year. It is estimated that 98% of the total sawtimber harvested in this area would be hardwoods, primarily oak (50-70%), with maples, poplar, hickory, beech, ash, cherry, elm, locust and other hardwoods making up the remainder. As much as 15% of the total can be an unclaimed burden or solid waste disposal problem for the generating sawmills. The rest of the sawdust has competitive uses as fuel, animal bedding, charcoal wood or miscellaneous wood products. An evaluation of the competitive market forces indicates that a facility sized to process 2,000 tons/day sawdust will find available a reliable (666,000 tons/year), reasonably priced source of raw material in the area. Raw material costs contribute significantly to the cost per gallon of denatured fuel, and transportation costs can be as high as 100% of the green sawdust. As expected, proximity to the source of raw materials is one of the most important engineering siting factors for selecting a potential greenfield site for construction of a sawdust to ethanol facility.

A technical evaluation of the BTE process for sawdust was performed to identify other facility requirements or considerations, and to establish production capabilities. From 2,000 tons/day "green" sawdust (50% moisture), 70% of the dry feedstock are hexans (cellulose) and pentosans (xylan), which are converted to glucose and xylose and fermented to ethanol at a yield of 87.4 gallons (100% ethanol) per dry ton of sawdust. The majority of the remaining lignin (24%), unconverted xylan, cellulose, solubles and ash are processed as boiler fuel, with a small percentage disposed of as solid waste or processed in the wastewater treatment system. Based on 333 days/year (7,992 hours) operating schedule, the manufacturing facility could produce more than $30MM gallons/year of denatured ethanol fuel (including fusel oils and 5% gasoline). Though solid byproduct and liquid losses are minimal, the BTE facility would represent a major source of air emissions due to the ethanol or volatile organic compound (VOC) emissions from fermentation, as well as particulate emissions associated with sawdust storage or handling. In addition to these environmental considerations and process requirements, the process flow diagrams, material balance and equipment list were used to develop a site layout that indicated 50 acres would be required to construct a "greenfield" facility in the tristate area.

Economic development councils, chambers of commerce and real estate agencies were contacted in a 56 county area surrounding the centroid of the hardwood saw mill area. Responses to inquiries were prescreened to ensure the sites met minimum facility requirements. Twenty two sites were surveyed to verify information and identify the site or sites which met technical, economic, environmental, and community siting factors. One "greenfield" site in West Virginia was selected to complete the refined cost estimates for a greenfield site. The South Point Ethanol Plant (SPE) site was utilized to define the costs associated with construction of the BTE facility at an existing facility.

Capital costs for the BTE facility of the greenfield site are estimated to be $110MM in 1995 dollars. By comparison, similar capital costs for a BTE plant at the existing ethanol production SPE plant are estimated at $81MM, assuming the SPE surplus boilers can burn lignin and eliminate the need to purchase a high pressure boiler/turbogenerator system.

The economics favor the existing site due to this capital savings and the considerable saving projected for administrative and general costs. However, these differences are somewhat mitigated by the loss of export power sales and the need to import power (offset somewhat by the fuel credit from replacing coal with lignin). The resulting estimated difference between the two sites represents about $0.10 per gallon of ethanol produced.

Costs for a 40 ton green sawdust per day engineering demonstration unit (EDU), for interim testing and process evaluation have been estimated at $10.8MM.

Financial pro forma income statements were developed for a set of base case assumptions, and sensitivity analyses were performed on major assumptions. The results indicate that a 1995 selling price of $0.95 per gallon ethanol selling price for the existing SPE site and a $1.04 per gallon for the greenfield site would be economically acceptable, assuming these prices escalated along with inflation. If, however, the price of ethanol does not escalate with inflation, as assumed, then in order to be economically acceptable, a selling price of $1.10 per gallon and $1.21 per gallon would have to be available (for the existing and greenfield sites, respectively) at the time the plant becomes fully operational. These acceptable selling prices are, however, based on ethanol price escalating in proportion to variable costs from that point forward.

A master schedule was prepared for the installation of the BTE facility and engineering demonstration unit (EDU) over a five and a half year period. The first two years (1995-97) are tentatively scheduled for operation of the PDU and design, construction and operation of the EDU, culminating in a reevaluation of the commercial plant economics and the formation of a financial/management consortium of owners and investors. Construction of the plant is tentatively scheduled to start after this period, with full scale operation after the fifth year.

3.0
LIST
OF
FIGURES,

TABLES,

[included in text]

AND

APPENDICES

[at end of report]

10.0 Appendices

A. Environmental Calculations

B. Site Survey Information Request

C. Site Survey Communications Summary

D. Site Survey Initial Site Screening

E. Site Survey Evaluations

F. Environmental Database

G. Site Survey Final Ranking of Sites

H. Process Equipment Listing

I. Cost Estimate Detail: Greenfield Site (Millwood, WV)

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K. Business Interest Solicitation Letter and Mailing List

4.0
PROCESS
FACILITY REQUIREMENTS

4.0 Process Facility Requirements

4.1 Site Selection: Minimum Feedstock Supply Quantities

4.1.1 *Summary*

A total of approximately 750,000 green tons per year (50% moisture content), 2,000 green tons per day of hardwood sawdust is available as a feedstock for the proposed Ethanol plant.

4.1.2 *Background Information/Sources of Information*

Information supplied by the state divisions of forestry for Kentucky, Ohio, and West Virginia as well as the United States Department of Agriculture formed the basis for much of this section of the report. Verification of this data was made by contacting a wide sample of sawmill operators and comparing their responses with that of published data.

4.1.3 *Terminology*

Terminology within the published data and that given by many of the respondents is not entirely consistent and necessitates conversion into a common unit of measure. Conversion rates and equivalent factors are as follows:

- 1 cu.ft. of green dust — 42 lbs.
- 1,000 board ft. of sawn hardwood — 0.65 ton of hardwood sawdust
- 1,000 board ft. of sawn hardwood — 0.35 to .90 ton of soft hardwood dust
- 1,000 board ft. of sawn hardwood — 0.5 to 1.35 tons of hard hardwood dust
- 1 cord of stacked wood — 85 cu.ft of solid wood
- 1 ton of green dust — 0.565 ton of oven dried sawdust
- 1 semi truck load (approx. 40 cu.yd.) — 22.5 tons of green sawdust
- 1 rail car load (approx. 90 cu.yd.) — 50 tons of green sawdust

4.1.4 *Findings*

The total amount of sawdust generated by the primary wood industries for the three states is approximately 1,200,000 "green" tons per year, which breaks down as follows:

- Kentucky.......................500,000 green tons per year
- West Virginia...............450,000 green tons per year
- Ohio.............................250,000 green tons per year

The primary industries tabulated here do not include dry kiln operations and pallet & skid producers. Output from secondary wood manufacturers (those manufacturers who produce products from wood supplied by others) is also not included. The sample of sawmills and related primary wood industries is as follows:

- Kentucky — 450 sawmills and related primary wood industries
- Ohio — 225 sawmills and related primary wood industries
- West Virginia — 225 sawmills and related primary wood industries

The largest 25% of the primary wood industry operators produce 80% of the total sawdust generated. Size of facility versus output by facility and cumulative capacity is shown in Figures 4-1, 4-2, and 4-3.

The residue produced from milling operations consists of approximately 20% bark, 50% coarse materials (chips, edgings, trimmings, slabs) and 30% sawdust. The greatest use for the residue is directly related to the region where it is generated. Most of the mill operators regard their sawdust as a useless waste by-product of the operation and are anxious for the opportunity to rid themselves of it. Of the total quantity of sawdust generated, some of the primary consumer uses are as follows:

- Fuel — 50 to 60% of the total output
- Animal bedding — 35% (Ohio's output)
- Charcoal wood — (20% of West Virginia's output)
- Miscellaneous — 10% of the total output
- Unclaimed — 1 to 15% of the total output

The current selling price of "green" sawdust is variable and depends on who is paying the freight costs. (in many cases it is free to those who can come to the site, load, and haul it away themselves). Some operations simply have to pay truck drivers to haul it away. They in turn may sell it at a small profit over their freight costs. The overall composite average selling price range is between $5 and $10 dollars per green ton delivered to the customer.

The 50 largest suppliers in Ohio produce a total of 200,000 tons per year (Fig. 4-1). The 50 largest suppliers in West Virginia produce a total of 350,000 tons per year (Fig. 4-2). The 100 to 150 largest suppliers in Kentucky produce a total of 375,000 tons per year (Fig. 4-3). The secondary wood manufacturing industry's production of sawdust adds more to this total.

4.1.5 *Assumptions*

The assumption and considerations used in determining the availability within the three (3) states are as follows:

- Essentially all (95%) of the generated sawdust in the region is available if the price is high enough.

- The more consistent the consumer is in accepting the bulk of the suppliers' residue the more favored this consumer will be to the supplier.

- A substitute for agricultural use will not be available at the current price level. If all or the greatest percentage of the generated output is needed, then the competing market forces will tend to increase the selling price to the price of straw or a higher priced substitute.

- A substitute for fuel uses due to competing market forces will increase the price past that of coal, oil and gas fuel substitutes due to the conversion costs to alternate fuels and the fuel costs themselves. If the current cost of coal is $25 per ton delivered and the heating value is 12,500 Btu per pound then the cost per million Btu is $1.00. If the cost for sawdust is $7.50 per ton delivered and the heating value is 4,900 Btu per pound then the cost per million Btu is $0.76. If the price of sawdust rises, then the current users of sawdust as a fuel will consider converting to an alternative fuel, such as coal.

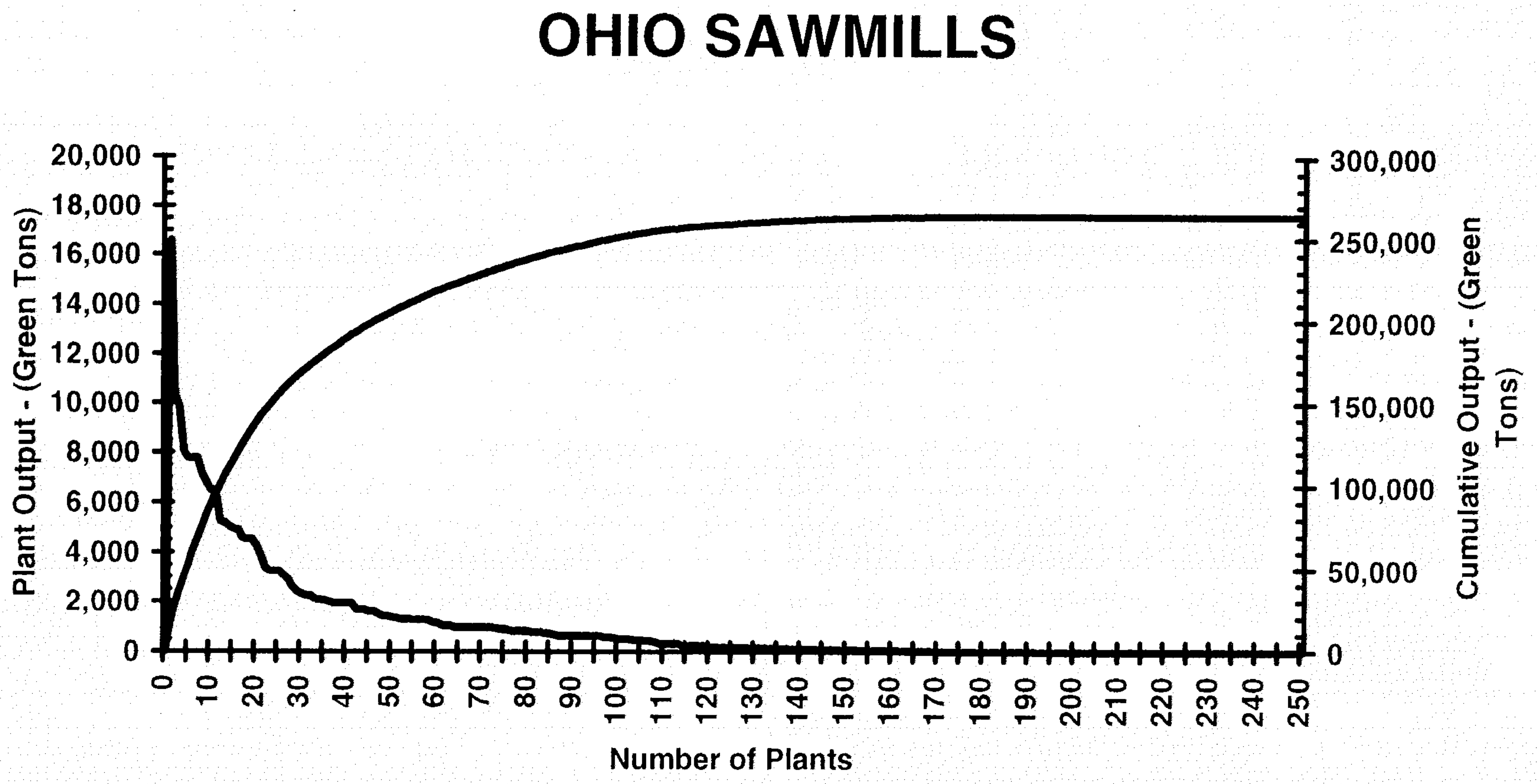
- Transportation costs from sawmills at distant locations will increase the price to the level where it would not be economically viable.

- Assuming a maximum trucking distance of 100 miles at a cost of $1.50 per loaded mile on a 22 ton capacity truck, the freight cost would be $6.80 per ton. If the distance was 50 miles at a cost of $1.80 per loaded mile, the freight cost would be $4.10 per ton. This compares closely to the quoted delivered price stated by many of the sawmill operators. In any case, transportation costs, along with the competitive market forces related to the demand for large quantities and the prices of alternative fuels or agricultural substitutes , will set the new selling price for sawdust residue.

- In Kentucky, the data shows the availability of an additional 100,000 tons per year from wood and pallet manufacturers. Assuming a similar ratio in Ohio and West Virginia, an estimated additional 170,000 tons per year (20% of the supply of the 200 largest primary wood industry output) is available.

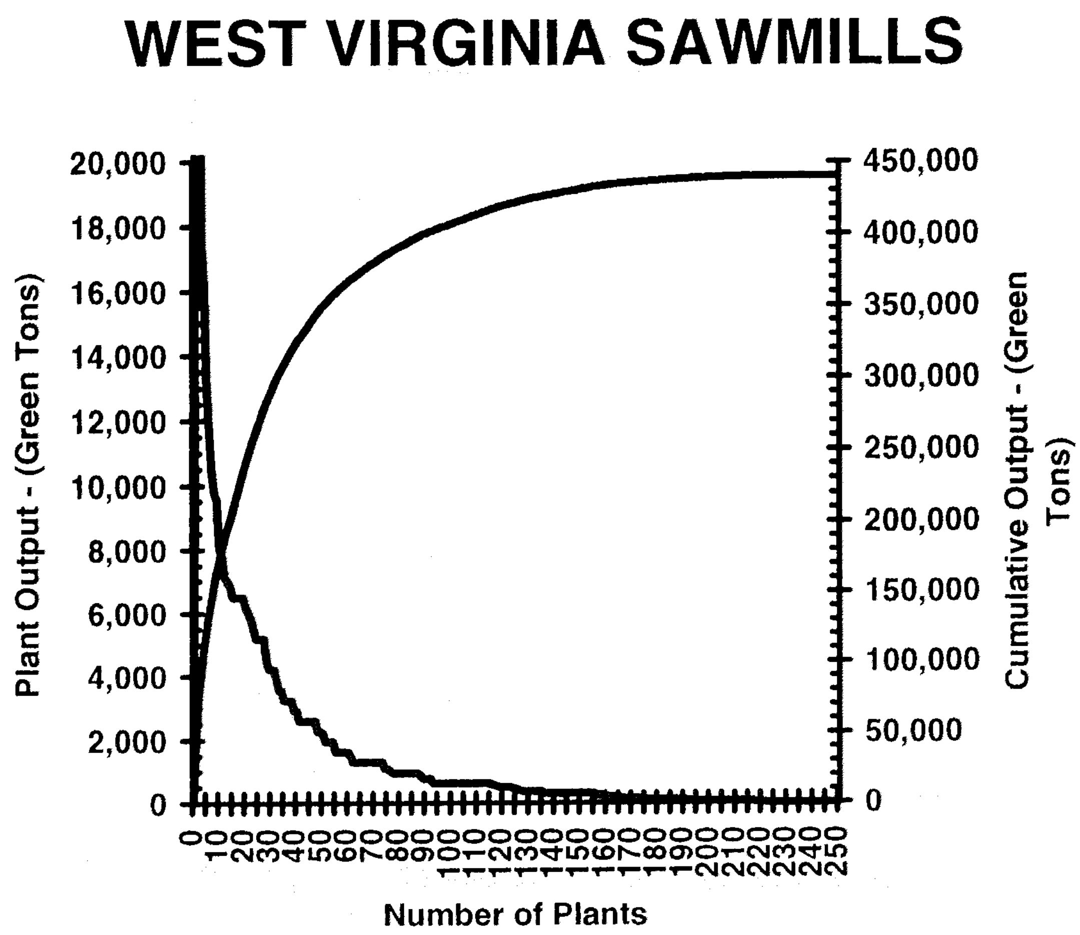
4.1.6 *Analysis*
Assuming that 60% of the largest suppliers in Ohio (40% animal bedding, etc.), 75% of the largest suppliers in West Virginia (25% goes to charcoal, etc.), and 70% of the largest suppliers in Kentucky (30% goes to charcoal, etc.) enter into supply contracts with the ethanol producers, then the total available would be 640,000 green tons per year. When the output of 20% of the total (from secondary manufacturers) is added a total of approximately 750,000 tons is available.

4.1.7 *Comments, Considerations, and Reservations*
To enhance the availability of feed stock, the area of supply of raw materials, should be expanded to include the top half of Tennessee and the western portion of Virginia. The boundaries of supply should be set by economic factors, not state lines.

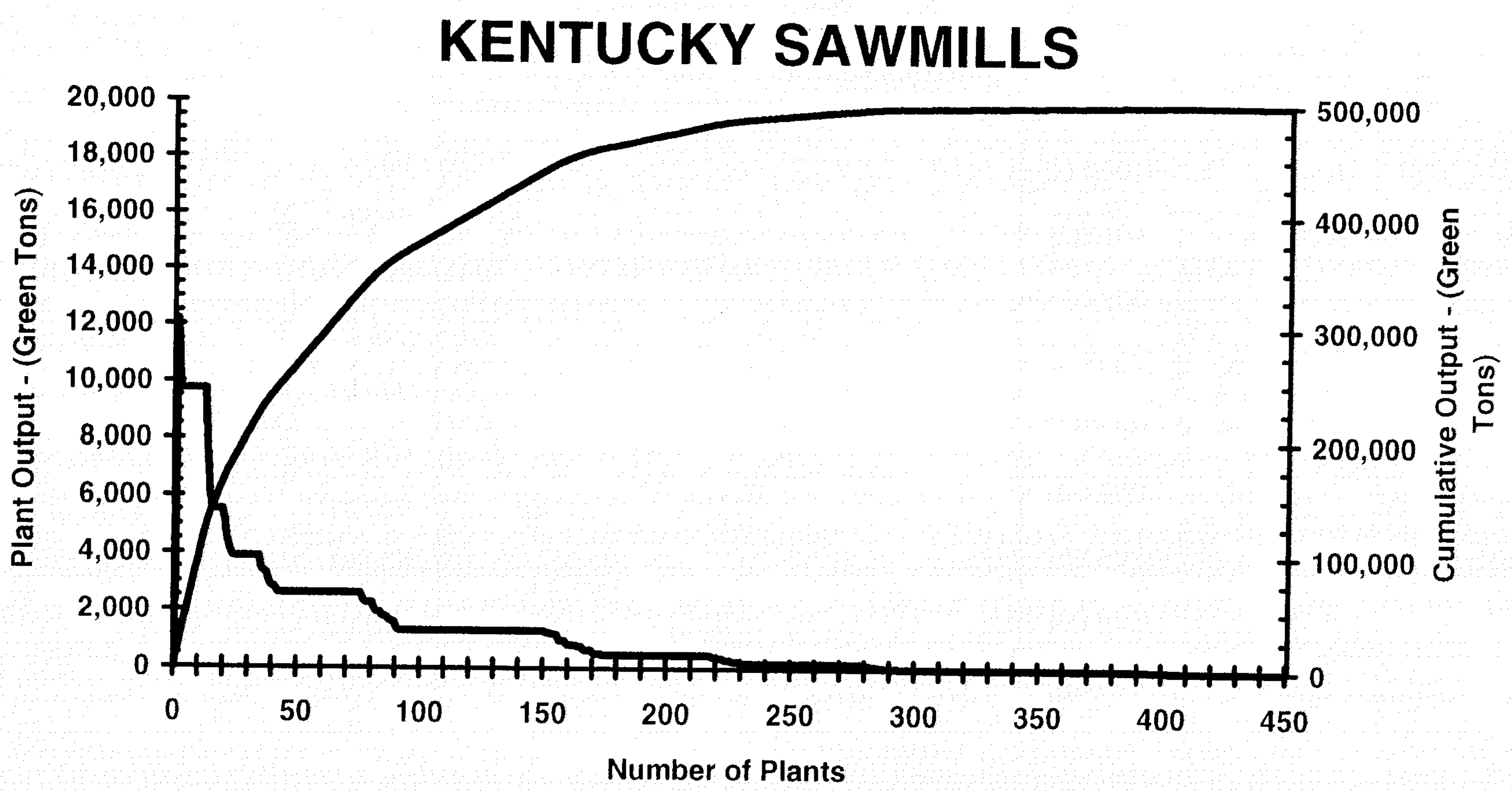


Ohio Sawdust Availability
Figure: 4-1

Figure: 4-2 W. Virginia Sawdust Availability



W. Virginia Sawdust Availability
Figure: 4-2



Kentucky Sawdust Availability
Figure: 4-3

Figure: 4-3 Kentucky Sawdust Availability

4.2 Ethanol Production Rate, Feedstock, Composition, & Solid By-Product

4.2.1 *Summary*

Ethanol Production Rate

The calculated ethanol production rate is 87,400 gallons per day (100% ethanol basis). This corresponds to 87.4 gallons per dry ton of sawdust. The composition prior to denaturation is 99.2 wt % (99.3 vol. %) ethanol, so the actual product (after adding about 200 gpd of fusel oil) will be 88,230 gallons per day prior to denaturing, and 92,650 gallons per day after denaturing with 5% gasoline. The factors that result in the projected yield of 87.4 gallons per ton are discussed below.

Feedstock Composition

The feedstock is 2,000 tons per day "as is" hardwood sawdust having 50% moisture. The assumed analysis matches that which was previously used in the SERI study using hardwood chips (46.2% hexans, 24.0% penntosans, 5.6% solubles, 0.2% ash, and 24.0% lignin).

Solid By-Product

Solid by-product (primarily lignin) production rate is calculated at 423 tons per day (dry basis). The moisture content is assumed to be 50%. This material, along with bio-gas generated from the waste treatment anaerobic digestor is used as fuel in the facility's boiler.

4.2.2 *Assumptions and Considerations*

Yield factors are, in most cases, the same as those used in the SERI hardwood chip study.

Xylan to Ethanol	Factor
• Theoretical xylan to xylose	1.136
• Acid hydrolysis yield	0.80
• Xylose recycle factor*	1.093
• Fraction hydrolysate to fermentation	0.968
• Theoretical xylose to ethanol yield	0.511
• Fermentation efficiency	0.855
• Fermentation loss factor**	0.994
• Resulting overall xylan yield factor	0.417
• Overall xylan yield: 2,000 x (.24 x .417) / 6.61 =	30.3 gal/ton

$$\text{(lb/ton)} \times \frac{\text{(lb ethanol)}}{\text{lb feed}} \,/\, \text{(lb/gal)}$$

* The recycle factor accounts for unreacted xylan and xylose that is returned with recycled process water.

** The fermentation loss factor is based on Simulation Sciences correlations for liquid activity coefficients and agrees well with published data for fermenter vent losses of ethanol.

Cellulose to Ethanol	Factor
• Theoretical cellulose to glucose	1.111
• Acid hydrolysis yield	0.999
• Cellulose recycle factor	1.004
• Fraction hydrolysate to SSF	0.979
• Enzyme hydrolysis yield	0.87
• Theoretical glucose to ethanol yield	0.511
• SSF fermentation yield	0.85
• Fermentation Loss Factor**	0.991
• Overall cellulose yield factor	0.4085
• Overall cellulose yield: 2,000 x (.462 x .4085) / 6.61 =	57.1 gal/ton

$$\text{(lb/ton)} \times \frac{\text{(lb ethanol)}}{\text{lb feed}} \; / \; \text{(lb/gal)}$$

Total Fermentation Yield: 30.3 + 57.1 =	87.4 gal/dry ton
CO2 Scrubber Recovery	.04 gal/dry ton
Distillation Factor	0.995
Plant Ethanol Yield	87.4 gal/dry ton

Solid By-Product

Key assumptions used in determining solid by-products are:

- Sawdust feedstock composition is 24% lignin
- Yield factors for ethanol are as listed above and roughly 0.97 lb. of CO_2 generated per lb. of fermentation ethanol (includes carbon dioxide from fermentation by-products).
- Ammonia is used to neutralize after acid hydrolysis in order to minimize calcium (gypsum) fouling in distillation.
- Solids separation using solid bowl centrifuges achieves 50% moisture in the solids stream and 0.2% suspended solids in the centrate.

4.3 Process Description

This section provides a description of the processing steps and associated utilities for producing ethanol from hardwood sawdust. Process flow diagrams (Figs.4-4 through 4-16) and material balances (Tables 4-1 through 4-9) for the described Greenfield Process follow this section. As directed by NREL, the process is patterned after the report by SERI for converting hardwood chips to ethanol, SERI/TP-232-4255 dated June 1991. A description is also included at the end of this section regarding changes that have been incorporated for installation of the process at the South Point Ethanol site where certain infrastructure and utilities are already in place.

4.3.1 Area 100: Receiving, Storage, and Feeding

Sawdust is brought in by rail and truck. Bottom discharge rail cars will be used to unload into a pit. Trucks will be emptied by either bottom discharge or by the two truck dumpers which tilt the trucks to discharge out the back into the pit. Dumped material will be loaded via short drag link conveyors to a belt conveyor. The convey rate of the incoming material will be several times the plant utilization rate, to permit speedy offloading at delivery. This conveyor will carry the material over to a storage pile. The storage pile should allow for about a 8-10 day supply of sawdust. A radial stacking/reclaim conveyor is used to move sawdust from the pile to a belt conveyor that transports the sawdust to the process, via a magnetic iron separator, to the prehydrolysis section.

4.3.2 Area 200: Prehydrolysis

Sawdust is delivered to a two-stage Impregnator/Prehydrolysis Reactor. Concentrated sulfuric acid is premixed to a diluted concentration that results in 0.85 wt% sulfuric acid after mixing with incoming feedstock moisture and preheating steam. The Impregnator and Prehydrolysis Reactor are sized for 10 minutes residence time each (sawdust at 20 lb/ft3 density). 50 psig steam is injected to preheat the material to 100°C in the Impregnator and 150 psig steam is injected in the Reactor to reach 160°C. The acid hydrolyzed material is then flash cooled and diluted to about 12% suspended solids. This material is neutralized using ammonia, cooled to 37°C, and transferred to xylose fermentation and cellulase production.

4.3.3 Area 300: Xylose Fermentation

Hydrolyzed material is fermented in two parallel continuous fermenter trains to produce ethanol from xylose using cultured E. coli. The E. coli is grown in a series of aerobic batch fermenters to produce 10% inoculum to the first fermenter in each train.

The E. coli seed fermenters are sized with 33% freeboard to allow for aerated liquid expansion. Aeration rates are to be 0.2 vvm, and an agitation power of 1 hp/1,000 gal is used. Each successive seed fermenter is supplied 10% inoculum from the preceding fermenter, and each seed fermenter cycle is figured at 24 hours with 12 hours fermentation time. Small seed fermenters use compressed air for transfer, and the final two seed fermenters use pump transfer. Seed production is maintained on an ongoing basis such that a fresh batch of seed is available every 24 hours. After a batch is completed, it is transferred to one of the continuous fermenter trains.

Two parallel xylose fermenter trains are included. Each train includes four fermenters in series, sized for a total retention time of about 48 hours at 95% volume utilization. One additional fermenter is included to allow for bypassing of one fermenter at any given time for cleaning and sterilizing. A fermenter (service) pump is included to handle transfers when emptying a fermenter for cleaning. Otherwise, flow is by gravity to each succeeding fermenter. Provision for aeration is included for the first and second fermenter in each train to promote initial E. coli growth. Agitation power is set at about 0.1 hp per 1,000 gallons. Side entering agitators are used. Product from xylose fermentation is transferred to SSF, and xylose vents are released to the atmosphere.

4.3.4 Area 400: Cellulase Production

Trichoderma reesei is cultured for use as cellulase to break down the cellulose into fermentable sugars. About 2.1% of the hydrolyzed feedstock is used for cellulase production. Three batch fermenters are used with a batch cycle time of 6 days, thus producing a fresh batch every 2 days. A hold tank is provided for storing finished cellulase which is then fed on a continuous basis to SSF. Each cellulase fermenter is sized with 33% excess volume to allow for aeration volume. The aeration rate is 0.15 vvm and the agitation power is set at about 2 hp/1,000 gal. Sterilized corn steep liquor and other nutrients are provided for fungus growth. Sterilized anti-foam is also provided. Cooling is provided by chilled water jacketing of the fermenters to maintain 28°C.

Cellulase seed is cultured in successively larger fermenters with each fermenter supplying 5% inoculum to the next fermenter. The final seed fermenter, in turn, provides 5% inoculum to each of the three final fermenters on a 2 day cycle. Two parallel trains of seed fermenters are used with each train being on a 4 day cycle to meet the required schedule.

4.3.5 Area 500: Simultaneous Saccharification and Fermentation (SSF)

The cellulose content of the feedstock is fermented by SSF using T. reesie to convert the cellulose to fermentable sugars and simultaneously fermenting the sugars using two yeasts, Sacchromyces cerevisiae (S.c.) and Brettanomyces clausenii (B.c.). The SSF is carried out in four parallel continuous fermenter trains. The two yeast strains are grown in a series of aerobic batch fermenters to produce 10% inoculum of each yeast to the first fermenter in each train.

The yeast seed fermenters are sized with 33% freeboard to allow for liquid aeration. Aeration rates are to be 0.2 vvm. Agitation power of about 0.5 hp/1,000 gal is used for the final seed fermenters and 1.0 hp/1,000 gal is used for all other yeast seed fermenters. Each successive seed fermenter is supplied 10% inoculum from the respective preceding fermenter. The S.c. seed fermenter cycle is figured at 36 hours with 24 hours fermentation time, and the B.c. seed fermenters are figured at a 60 hour cycle with 48 hours fermentation time. The smaller seed fermenters use compressed air for transfer, and the final two seed fermenters use pumped transfer. Seed production is maintain on an ongoing basis such that a fresh batch of yeast seed is available if needed every 36 hours for S.c. and every 60 hours for B.c. After a yeast seed batch is completed, it is immediately transferred to one of the continuous fermenter trains.

Four parallel SSF trains are included. Each train includes four fermenters in series, sized for a total retention time of about 7 days at 95% volume utilization. Two additional fermenters are included (one each for two train pairs) to allow for bypassing of up to two fermenters at any given time for cleaning and sterilizing. Two fermenter (service) pumps are included to handle transfers when emptying fermenters for cleaning. Otherwise, flow is by gravity to each succeeding fermenter. Provision for aeration is included for the first and second fermenter in each train to promote initial yeast growth. Agitation power is set at about 0.1 hp per 1,000 gallons. Two side entering agitators are used on each fermenter. Product from SSF is transferred to distillation. SSF vents are sent a vent condenser that uses chilled water to recover about 30% of the vented ethanol vapor. The recovered vent condensate is combined with the SSF beer going to distillation.

to

4.3.6 Area 600: Distillation, Dehydration, and Solids Recovery

The distillation system uses a Beer Stripper and Rectifier to recover the ethanol and concentrate it to 192° proof ethanol (96 volume %) ethanol. This is followed by a benzene azeotropic dehydration distillation system to produce 199° proof ethanol.

A fusel oil cut is withdrawn near bottom of the rectifier in order to prevent fusel oil buildup in the column. This stream is washed with water which removes most of the ethanol and causes a fusel oil layer to separate. This fusel oil layer, which is less than 0.3% of the final product and is about 80% water free, is blended with the final, dehydrated ethanol product.

Distillation energy requirements are reduced by two-stage beer preheating. The first preheating uses spent stillage the heat source. This also serves to cool the stillage prior to lignin solids separation. The second stage of preheat uses flash steam from the acid prehydrolysis section.

Substantial energy conservation is achieved by operating the dehydration columns at elevated pressure (about 130 psig) and using their overhead vapors to generate low pressure steam which is used to supplement LP steam to the Beer Column.

The dehydration system uses benzene, which is recirculated and retained within the system, as a water entraining agent. The 192° proof Rectifier product is fed to the Anhydrous Column. An ethanol-water-benzene azeotrope is taken overhead from the Anhydrous Column. Upon condensing, the liquid forms two phases. One is rich in benzene and the other is rich in water. The benzene layer is returned to the column as reflux, and the water layer is sent to a second column where it is steam stripped to remove ethanol and benzene prior to its disposal. The dehydrated (199° proof) ethanol is removed as bottom product from the Anhydrous Column.

The spent stillage from the Beer Column contains lignin and other residual solids which are substantially insoluble in water. After they are cooled, they are centrifuged using solid bowl, decanter type centrifuges to recover a 50% solids slurry. This stream is sent to the boiler as fuel. About 70% of the centrate is recycled as process water makeup, and the remaining 30% is sent to waste treatment.

4.3.7 Area 700: Chemicals and Process Storage

This area includes tank storage and transfer pumps for various process and utilities requirements. Tankage for the following liquid materials are included:

Chemical	Capacity	No. of Days
• Ethanol Product	2 @ 500,000 gal	11
• Glucose Syrup	5,000 gal	50
• Sulfuric Acid	24,000 gal	9
• Fire Water	508,000 gal	---
• Ammonia	4 @ 20,000 gal	25
• Antifoam	1,000 gal	70
• Diesel Fuel	5,000 gal	---
• Gasoline	88,000 gal	17
• Corn Steep Liquor	18,000 gal	120
• Benzene	5,000 gal	60

4.3.8 Area 800: Waste Treatment and Power Utilities

Waste water is sent to anaerobic digestion where biogas (methane and carbon dioxide) is generated. This biogas, sludge from aerobic waste treatment, and stillage solids slurry are fired to the boiler to produce steam at 1,100 psig with 300° F superheat. Based on tabulated heating values, 255,000 lbs/hr of steam are generated.

This steam is used to generate power using an extraction, condensing turbine. About 80,500 lbs/hr of steam is extracted at 150 psig and 39,500 lbs/hr is extracted at 50 psig for process uses. The remaining steam is exhausted from the turbine to a vacuum condenser. Electric power in the amount of 22 MW is generated of which about 6.4 MW is used in the facility. The remaining power is sold to the power grid.

Fermenter Sterilizing

Fermenter cleaning sterilizing is carried out by use of rotary spraying of 2 to 3% hot caustic solution. The heating source will be live steam injection into the vessel that is being cleaned by the caustic solution. Heating will continue until a temperature of at least 180° F is reached, after which the hot caustic spray will be maintained for an additional period of about 2 hours.

Water Balance

Water inputs to the process are primarily in the form of direct contact steam for acid hydrolysis and distillation. Most of this water is separated by the stillage centrifuges and recycled as required for liquid makeup to hydrolysis and fermentation areas. The excess water from the stillage centrifuges goes to waste treatment along with the water removed by ethanol dehydration and flash steam condensate from acid hydrolysis. Spent cleaning solutions and various process LP vent liquids also go to waste treatment. Effluent from waste treatment is utilized for cooling tower makeup.

Fresh, filtered and treated well water is used for boiler feedwater makeup, the balance of cooling tower makeup, glucose dilution, cleaning solution makeup, and fusel oil washing.

Normally, the only waste liquid effluent from the plant will be well water filter backwash, boiler blowdown, and cooling tower blowdown.

Process Description-South Point Ethanol Site

The process is essentially the same for the South Point Ethanol (SPE) site as for the greenfield site. Maximum utilization of existing site infrastructure such as offices, rail siding, warehousing, product storage, and utilities would be incorporated into the SPE plant site design. The most notable difference for the SPE site is that the existing boilers would be utilized to generate steam for the existing corn ethanol plant as well as for the sawdust ethanol plant. Fuel credits for sawdust byproduct fuels are incorporated into the financial analysis for the SPE site.

PREHYDROLYSIS MATERIAL BALANCE
TABLE 4-1

BLOCK FLOW MATERIAL BALANCE, SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

AREA 200, SAWDUST PRETREATMENT

	Sawdust	Dilution Recyc Wt	H2SO4	Flashed Prhydrlzat	Flashed Steam	Recycled Water	Prhydrlzd Sawdust	Prhydrlzat Ammonia	Neutrlizd Prhydrlzat	Feed to Xyl Ferm	Feed to Cellulase	Prhydrlsis LP Stm	Prhydrlsis HP Stm	Prhydrlzat Clng Wtr	Reactor contents Before	
															Before	After
COMPONENT \ STREAM NUMBER	101	211	212	215	216	217	218	221	222	223	224	911	912	921	Reaction	Reaction
WATER	83,333	56,908	27	146,310	21,966	234,285	380,595		380,595	372,488	8,107	8,442	21,158	1,871,770	169,868	168,276
CELLULOSE	38,500	31		37,337		127	37,464		37,464	36,666	798				38,531	37,337
XYLAN	20,000	2		1,402		8	1,410		1,410	1,379	30				20,002	1,402
SOLUBLE SOLIDS	4,667	3,231		7,897		13,301	21,198		22,514	22,034	480				7,897	7,897
ASH	167	57		224		236	460		460	450	10				224	224
LIGNIN	20,000	135		20,135		557	20,692		20,692	20,251	441				20,135	20,135
XYLOSE		329		18,511		1,355	19,866		19,866	19,442	423				329	18,511
HMF		8		30	8	31	61		61	59	1				8	38
FURFURAL		498		1,946	442	2,049	3,995		3,995	3,910	85				498	2,388
AMMONIA (AQUEOUS)		4		4		18	22		478	468	10				4	4
GLYCEROL		304		304		1,253	1,557		1,557	1,524	33				304	304
CELL MASS		28		28		114	142		142	139	3				28	28
CELLULASE		109		109		450	560		560	548	12				109	109
GLUCOSE				1,283			1,283		1,283	1,256	27					1,283
AMMONIA								456								
H2SO4			1,315	1,315			1,315								1,315	1,315
TOTAL	166,667	61,644	1,342	236,837	22,416	253,783	490,620	456	491,076	480,616	10,460	8,442	21,158	1,871,770	259,253	259,253
Temperature, C	16	90	20	100	100	90	100	25	100	37	37	147	186	30	160	160
Temperature, F	60	194	68	212	212	194	212	77	212	99	99	297	366	86	320	320
Pressure, psig					0.005			130				50	150		105	105
Specific Gravity (lb/ft3 for vapor & sawdust)	20	0.99	1.84	1.12	0.0373	0.99	1.05	0.60	1.05	1.08	1.08	0.1495	0.363	1.00	1.05	1.06
Flow,gpm (ft3/min for vapor & sawdust)	139	124	1	423	10,016	511	937	2	940	892	19	941	971	3,753	492	488

DESIGN BASIS:

Sawdust:	% Dry Basis
Hexans	46.20%
Pentosans	24.00%
Soluble Solids	5.60%
Ash	0.20%
Lignin	24%
Other	
Total	100.00%
Moisture	50%
Tons/day, as is	2000
Design Ambient, F.	60
% solids check	0.35
Fraction feed to Cellulase =	0.0213

Recycle Water:	Stream 211	Stream 622
Water	92.317%	92.317%
Cellulose	0.050%	0.050%
Xylan	0.003%	0.003%
Sol. Solid	5.241%	5.241%
Ash	0.093%	0.093%
Lignin	0.219%	0.219%
Xylose	0.534%	0.534%
HMF	0.012%	0.012%
Furfural	0.807%	0.807%
Am (aq)	0.007%	0.007%
Glycerol	0.494%	0.494%
Cell Mass	0.045%	0.045%
Cellulase	0.178%	0.178%
Total	7.683%	7.683%

Recycle Water temperature =	90	°C
Recycle Water S.G. =	0.99	
Cooling Water temperature =	30	°C
Cooling Water S.G. =	1.00	
Cooling Water temp. rise =	14	°C
Chilled Water temperature =	10	°C
Chilled Water S.G. =	1.00	
Chilled Water temp. rise =	8	°C
Process Air temperature =	28	°C
Process Air pressure =	45	psig
Process Air density =	0.298	lb/ft3
Process Water temperature =	15	°C
Process Water S.G. =	1.00	
Specific heat of Wood =	0.32	BTU/lb-°F
Specific heat of Water =	1.00	BTU/lb-°F

STEAM:							
LP Stm Enthalpy, Btu	1179	psig =	50	°F =	297	lb/ft3 =	0.1495
HP Stm Enthalpy, Bt	1195.5	psig =	150	°F =	366	lb/ft3 =	0.363

TABLE 4-2
XYLOSE FERMENTATION MATERIAL BALANCE

BLOCK FLOW MATERIAL BALANCE, SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

AREA 300, XYLOSE FERMENTATION

	Feed to Xyl Frmtn	E. coli Seed	Feed to Xyl Frmtr	Feed to E. coli	E. coli to Xyl Frmtr	NH3 to E. coli	NH3 to Xyl Frmtr	Xyl Frmtr Vent	Frmtr Brth to S.S.F.	E. coli Recyc Wtr	E. coli Frmtr Vnt	E. coli Clng Wtr	Xyl Frmtr Clng Wtr	E. coli Prcs Air	Xyl Frmtr Prcs Air
COMPONENT \ STREAM NUMBER	223	300	301	302	303	304	305	306	308	312	313	922	923	941	948
WATER	372,488		368,357	4,131	7,248			227	375,377	3,182	65	17,018	283,858		
CELLULOSE	36,666		36,260	407	408				36,668	2					
XYLAN	1,379		1,364	15	15				1,380	0					
SOLUBLE SOLIDS	22,034		21,790	244	549				23,733	181					
ASH	450		445	5	8				453	3					
LIGNIN	20,251		20,026	225	232				20,259	8					
XYLOSE	19,442		19,227	216					1,394	18					
HMF	59		59	1	1				60	0					
FURFURAL	3,910		3,867	43	71				3,938	28					
AMMONIA (AQUEOUS)	468		463	5	5				647	0					
GLYCEROL	1,524		1,507	17	34				1,541	17					
CELL MASS	139		137	2	127				264	2					
CELLULASE	548		537	6	12				549	6					
GLUCOSE	1,256		1,242	14					180						
AMMONIA							179								
ETHANOL								56	8,889						
CARBON DIOXIDE								8,556							
AIR											1,614			1,614	15,245
TOTAL	480,616	<< 1	475,281	5,330	8,712	<< 1	179	8,839	475,332	3,446	1,679	17,018	283,858	1,614	15,245
Temperature, C	37	37	37	37	37	25	25	37	37	90	37	30	30	28	28
Temperature, F	99	99	99	99	99	77	77	99	99	194	99	86	86	82	82
Pressure, psig						130	130							45	45
Specific Gravity (lb/ft3 for vapor)	1.08		1.08	1.08	1.05	0.60	0.60	0.106	1.058	0.99	0.070	1.00	1.00	0.298	0.298
Flow,gpm (ft3/min for vapor)	892		883	10	17		1	1,390	898	7	400	34	569	90	854

DESIGN BASIS:

Sugar converted =	100%		Vent Composition:	
	0.5	lb cell mass/lb Sugar	Ethanol mole fraction	0.0091
Soluble solids created with cell mass =	0.5	lb sol. solids/lb Sugar	$\gamma EtOH$ =	4.2262
Xylose diverted to E. Coli propagation =	1.11%		γH_2O =	1
Ammonia required for pH control =	0.02	lb NH_3/lb Ethanol produced	yEtOH =	0.0058
Xylose converted to Ethanol =	85.5%		yH_2O =	0.0606
Specific heat of CO_2 =	0.21	BTU/lb-°F	yCO_2 =	0.9335
Specific heat of Ethanol (gas) =	0.4	BTU/lb-°F	xEtOH =	0.0063
Heat duty of Xylose fermenters =	15	BTU/hr/lb feed	xH_2O =	0.0257
Heat duty of E. Coli fermenters =	49	BTU/hr/lb feed	xCO_2 =	0.9679
Heat of vaporization of Water (Atm) =	1050	BTU/lb		
Heat of vaporization of Ethanol =	395	BTU/lb	yH_2O =	0.0612

TABLE 4-3
CELLULASE FERMENTATION MATERIAL BALANCE

BLOCK FLOW MATERIAL BALANCE. SCREENING STUDY FOR SAWMILL WASTE-TO-ETHANOL STUDY

AREA 400, CELLULASE PRODUCTION

	Feed to Cellulase	T. reesei Seed	T.r. Seed Nutrients	T.r. Seed Glucose	T.r. Seed Recyc Wtr	T.r. Seed Vent	Xyl to Cellulase	Xyl to Seed	T.r. Seed to Prdctn	Cellulase Recyc Wtr	Cellulase Nutrients	Cellulase Anti-Foam	Cellulase Vent	Cellulase to S.S.F.	Cellulase LP Stm	Cellulase Prcs Air	T.r. Seed Prcs Air	Cellulase Chld Wtr	T.r. Seed Chld Wtr
COMPONENT \ STREAM NUMBER	224	400	402	403	404	408	411	412	413	414	415	417	419	420	913	942	943	952	954
WATER	8,107			1	2	16	8,082	25	11	2,668			316	10,445	12,000			392,686	2,051
CELLULOSE	798				0		796	2		1									
XYLAN	30				0		30	0	0	0				30					
SOLUBLE SOLIDS	480				0		478	1	55	151				2,324					
ASH	10				0		10	0	0	3				12					
LIGNIN	441				0		439	1	1	6				447					
XYLOSE	423				0		422	1		15									
HMF	1				0		1	0	0	0				2					
FURFURAL	85				0		85	0	0	23				108					
AMMONIA (AQUEOUS)	10				0		10	0	0	0				10					
GLYCEROL	33				0		33	0	0	14				47					
CELL MASS	3				0		3	0	0	1				242					
CELLULASE	12				0		12	0	0	5				341					
GLUCOSE	27			0			27	0						27					
NUTRIENTS			7								87								
ANTI-FOAM												4							
AIR						695							20,252			21,127	741		
TOTAL	10,460	<< 1	7	1	2	712	10,428	32	68	2,890	87	4	20,567	14,036	12,000	21,127	741	392,686	2,051
Temperature, C.	37	28	25	25	90	28	37	37	28	28	121	121	28	28	147	28	28	10	10
Temperature, F.	99	82	77	77	194	82	99	99	82	82	250	250	82	82	297	82	82	50	50
Pressure, psig															50	45	45		
Specific Gravity (lb/ft3 for vapor)	1.08				0.99	0.073	1.08	1.08	1.08	0.99		0.92	0.073	1.09	0.1495	0.298	0.298	1.00	1.00
Flow,gpm (ft3/min for vapor)	19				0	162	19	0	0	6		0	4,696	26	1,338	1,183	42	785	4
															scfm=	4695	165		
DESIGN BASIS:																			
Volume of FM-400 =	117000	gal		Vent Composition:															
Xylose diverted to T. Reesei propagation =	0.31%				yH2O =			0.0367											
Ammonia required for pH control =	0.045	lb NH3/lb Sugar																	
Air Input =	0.15	v v m		Heat duty of Cellulase fermenters =				420	BTU/lb										
Air uptake rate =	42	mMol O2/Liter-Hr		Heat duty of T. Reesei fermenters =				436	BTU/lb										
Anti-Foam required =	1	ml/Liter fermenter volume																	
Anti-Foam specific gravity =	0.92																		
Nutrients converted to cell mass =	100%																		
Sugar converted =	100%																		
Final cell mass concentration =	20	gm/liter																	
Cellulase yield =	202	IU/gm sugar																	
Enzyme activity =	732	IU/gm enzyme																	

SIMULTANEOUS SACCHARIFICATION & FERMENTATION MATERIAL BALANCE
TABLE 4-4

BLOCK FLOW MATERIAL BALANCE, SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

AREA 500, SIMULTANEOUS SACCHARIFICATION AND FERMENTATION

	Frmtr Brth to S.S.F.	Cellulase to S.S.F.	S.c. Seed	Diluted Glucose	Cellulase to S.c.	E. Coli to S.c.	S.c. Seed to S.S.F.	B.c. Seed	Diluted Glucose	Cellulase to B.c.	E. Coli to B.c.	B.c. Seed to S.S.F.	Cellulase to S.S.F.	E. Coli to S.S.F.	S.S.F. Feed	S.S.F. Product
COMPONENT \ STREAM NUMBER	308	420	500	501	502	503	504	505	506	507	508	509	510	511	513	514
WATER	375,377	10,445		297	321	11,487	13,129		306	321	11,487	14,451	9,804	352,404	389,788	385,721
CELLULOSE	36,668					1,122	958				1,122	958		34,424	36,340	4,724
XYLAN	1,380	30			1	42	43			1	42	43	28	1,295	1,410	282
SOLUBLE SOLIDS	23,733	2,324			71	726	900			71	726	909	2,181	22,281	26,271	26,271
ASH	453	12			0	14	14			0	14	14	12	425	466	466
LIGNIN	20,259	447			14	620	634			14	620	634	420	19,019	20,706	20,706
XYLOSE	1,394					43	43				43	43		1,309	1,394	2,675
HMF	60	2			0	2	2			0	2	2	2	56	62	62
FURFURAL	3,938	108			3	120	124			3	120	124	102	3,697	4,046	4,046
AMMONIA (AQUEOUS)	647	10			0	20	20			0	20	20	10	608	658	658
GLYCEROL	1,541	47			1	47	49			1	47	49	45	1,447	1,589	2,475
CELL MASS	264	242			7	8	118			7	8	127	227	248	720	4,253
CELLULASE	549	341			10	17	27			10	17	27	320	516	890	890
GLUCOSE	180	27		17	1	6			34	1	6		26	169	195	
ETHANOL	8,889					272	272				272	272		8,345	8,889	24,033
CARBON DIOXIDE																
AIR																
ACETALDEHYDE																422
FUSEL OILS																35
TOTAL	475,332	14,036	<<1	314	431	14,545	16,333	<<1	340	431	14,545	17,672	13,174	446,242	493,422	477,719
Temperature, C.	37	28	37	25	28	37	37	37	25	28	37	37	28	37	37	37
Temperature, F.	99	82	99	77	82	99	99	99	77	82	99	99	82	99	99	99
Pressure, psig																
Specific Gravity (lb/ft3 for vapor)	1.06	1.09		1.02	1.09	1.06	1		1.03	1.09	1.06	1	1.09	1.06	1.06	1.03
Flow,gpm (ft3/min for vapor)	898	26		1	1	27	31		1	1	27	33	24	843	933	924

	SSF Vent to Cdnsr.	SSF Vent to Atm.	Vent C'ndnsate	Distillation Feed	S.c. Seed Vent	B.c. Seed Vent	Scrubber Feed	Scrubber Water	Scrubber Bottoms	Scrubber Vent	Seed Clng Wtr	S.S.F. Clng Wtr	S.c. Seed Prcs Air	B.c. Seed Prcs Air	S.S.F. Prcs Air	Condnsr Chld Wtr
COMPONENT \ STREAM NUMBER	515	516	517	518	519	520	530	531	532	533	924	925	945	946	949	955
WATER	313	87	247	385,969	159	318	66	2,000	2,000	66	59,914	356,255				18,031
CELLULOSE				4,724												
XYLAN				282												
SOLUBLE SOLIDS				26,271												
ASH				466												
LIGNIN				20,706												
XYLOSE				2,675												
HMF				62												
FURFURAL				4,046												
AMMONIA (AQUEOUS)				658												
GLYCEROL				2,475												
CELL MASS				4,253												
CELLULASE				890												
GLUCOSE																
ETHANOL	164	34	51	24,084			113		100	13						
CARBON DIOXIDE	11,832	3,273					11,832			11,832						
AIR		trace			5,968	11,936							5,968	11,936	53,609	
ACETALDEHYDE				422												
FUSEL OILS				35												
TOTAL	12,309	3,394	298	478,017	6,127	12,254	12,011	2,000	2,100	11,911	59,914	356,255	5,968	11,936	53,609	18,031
Temperature, C.	37	37	13	37	37	37	13	15	25	16	30	30	28	28	28	10
Temperature, F.	99	99	55	99	99	99	55	59	77	60	86	86	82	82	82	50
Pressure, psig													45	45	45	
Specific Gravity (lb/ft3 for vapor)	0.104	0.104	0.96	1.03	0.070	0.070	0.116	1.00	0.99	0.115	1.00	1.00	0.298	0.298	0.298	1.00
Flow,gpm (ft3/min for vapor)	1,969	543	0.6	924	1,458	2,916	1,724	4	4	1,725	120	714	20,051	40,102	3,002	36

DESIGN BASIS:

Specific heat of Water (vapor) =	0.45	BTU/lb-°F	Vent Composition:				
Conversion factor for Cellulose =	1.1111	lb Glucose/lb Cellulose	Ethanol mole fraction =	0.0199		Water Condensed =	79%
Cellulose converted =	87%		yEtOH =	4.0719		Ethanol Condensed =	31%
Conversion factor for Xylan =	1.1364	lb Xylose/lb Xylan	yH2O =	1			
Xylan converted =	80%		yEtOH =	0.0123		CO2 recovered (Xylose & SSF) =	50%
By-Product formed =	0.049	lb By-Product/lb Glucose	yH2O =	0.0600		EtOH recovered =	88%
Glycerol formed as By-Product =	0.512	lb Glycerol/lb By-Product	yCO2 =	0.9277		EtOH in Scrubber Product =	4.76%
Acetaldehyde formed as By-Product =	0.244	lb Acetaldehyde/lb By-Product	xEtOH =	0.0133			
CO2 formed with By-Product =	0.244	lb CO2/lb By-Product	xH2O =	0.0254			
Fusel Oils formed =	0.001	lb Fusel Oils/lb Glucose	xCO2 =	0.9612			
Yeast Cells formed =	0.1	lb Yeast Cells/lb Glucose					
Glucose converted =	100%		Heat duty of S.S.F. fermenters =	18	BTU/hr/lb feed		
	0.511	lb Ethanol/lb Glucose	Heat duty of Yeast fermenters =	44	BTU/hr/lb feed		
	0.489	lb CO2/lb Glucose					

DISTILLATION MATERIAL BALANCE
TABLE 4-5

BLOCK FLOW MATERIAL BALANCE, SCREENING STUDY FOR SAWMILL WASTE-TO-ETHANOL STUDY

AREA 600, ETHANOL RECOVERY

	Distillation Feed	Degasser Vent	Condnsr Vent	Vent C'ndnsate	Beer to Column	Overhead to R.C.	R.C. Btms to B.C.	Hot Stillage	Tempered Stillage	R.C. Overhead	R.C. Cond Vent	Vent C'ndnsate	Rectifier C'ndnsate	Reflux to R.C.	Rectifier Product	F.O. Draw
COMPONENT \ STREAM NUMBER	535	600	601	602	603	604	605	606	607	609	611	612	613	614	615	616
WATER	388,037				388,037	48,196	46,686	462,740	462,740	9,357	1	9,356	9,356	7,683	1,673	63
CELLULOSE	4,724				4,724			4,724	4,724							
XYLAN	282				282			282	282							
SOLUBLE SOLIDS	26,271				26,271			26,271	26,271							
ASH	466				466			466	466							
LIGNIN	20,706				20,706			20,706	20,706							
XYLOSE	2,675				2,675			2,675	2,675							
HMF	62				62			62	62							
FURFURAL	4,046				4,046			4,046	4,046							
AMMONIA (AQUEOUS)	658				658			658	658							
GLYCEROL	2,475				2,475			2,475	2,475							
CELL MASS	4,253				4,253			4,253	4,253							
CELLULASE	890				890			890	890							
ETHANOL	24,187				24,187	29,539	5,353	1	1	134,596	103	134,493	134,493	110,422	24,071	188
ACETALDEHYDE	422				422	422				464	413.9	50	50	41.7	8.4	
FUSEL OILS	35				35	35										47.8
TOTAL	480,189	trace	trace	trace	480,189	78,192	52,039	530,247	530,247	144,417	518	143,899	143,899	118,146	25,753	299
Temperature, C	37	90	37	37	91	101	101	113	90	90	79	79	79	79	79	90
Temperature, F	99	194	99	99	197	214	214	235	194	194	174	174	174	174	174	194
Pressure, psig						4										
Specific Gravity (lb/ft3 for vapor)	1.03				1.01	0.074	0.90	1.00	1.01	0.093	0.096	0.80	0.80	0.80	0.80	0.82
Flow,gpm (ft3/min for vapor)	925				954	17,517	116	1,064	1,049	25,987	90	360	360	296	64	1

	F.O. Return	F.O. Was Water	F.O. to Product	Dehydrtd Ethanol	H/C Stpr Bottoms	Beer Stpr LP Stm	Beer Stpr. Total Stm	Anhyd Col HP Stm	H/C Stpr HP Stm	Steam nrtr Stea	Degasser Clng Wtr	R.C. Clng Wtr	Product Clng Wtr	F.O. Draw Chld Wtr	Rctfr Vent Chld Wtr	Dehydrtn Chld Wtr
COMPONENT \ STREAM NUMBER	617	618	619	635	637	914		915	916	925	926	927	928	956	957	958
WATER	226	177	13	153	9,921	21,098	76,212	50,991	8,401	55,115		2,487,655		1,278		
CELLULOSE																
XYLAN																
SOLUBLE SOLIDS																
ASH																
LIGNIN																
XYLOSE																
HMF																
FURFURAL																
AMMONIA (AQUEOUS)																
GLYCEROL																
CELL MASS																
CELLULASE																
ETHANOL	177		11	24,071	0.3											
ACETALDEHYDE																
FUSEL OILS	12.5		35.3													
TOTAL	415	177	60	24,223	9,922	21,098	76,212	50,991	8,401	55,115		2,487,655		1,278		
Temperature, C	25	15	25	25		147	128	186	186	121	30	30	30	10	10	10
Temperature, F	77	59	77	77		297	263	366	366	250	86	86	86	50	50	50
Pressure, psig						50	15	150	150	15						
Specific Gravity (lb/ft3 for vapor)	0.89	1.00	0.84	0.793		0.1495	0.073	0.363	0.363	0.073	1.00	1.00	1.00	1.00	1.00	1.00
Flow,gpm (ft3/min for vapor)	1	0	0.14	61.12		2,352	17,458	2,341	386	12,625		4,988		3		

DESIGN BASIS:

Water to Fusel Oil Ratio =	5	lb Water/lb Fusel Oil		EtOH =	19%
Specific heat of Ethanol (liquid) =	0.35	BTU/lb-°F		Water =	22%
Specific heat of Fusel Oil =	0.6	BTU/lb-°F		Fusel Oil =	59%
Ethanol in product =	0.946	lb Ethanol/lb Product			
Ethanol recovered from beer =	100%		Composition of 616:		
Acetaldehyde in Vent =	98%			EtOH =	63%
Acetaldehyde recovered from beer =	100%			Water =	21%
Column bottoms temp. drop =	20	°C		Fusel Oil =	16%
Column reboiler duty =	1330	BTU/gal Beer			
Heat of vaporization of water (50 psig) =	910	BTU/lb	Composition of 617:		
Vent Composition:				EtOH =	15%
EtOH =	20%			Water =	82%
Acetaldehyde =	80%			Fusel Oil =	3%

WASTEWATER TREATMENT MATERIAL BALANCE
TABLE 4-6

BLOCK FLOW MATERIAL BALANCE. SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

AREA 600, LIGNIN SEPARATION AND DIGESTION

	Flash Cond. (g)	Flash Cond. (l)	Waste Water	Sludge to Boiler	Centrate to Tank	Centrate Water	Settlement Recyc.	Cntrl to Waste Tr	Recycle Water	Knockout Liquid	Anaerobic Feed	Biogas to Boiler	Aerobic Feed	Process Water	Sludge to Boiler	Aerobic Vent	WW Effluent	Equalztn Clng Wtr	CIP Waste	Aerobic Prcs Air	Recyc Wtr Chld Wtr
COMPONENT \ STREAM NUMBER	216	225	607	620	621	622	623	624	626	627	629	630	631	632	633	634	638	929	931	947	953
WATER	21,966	21,966	462,740	26,944		435,796		138,752	5,851		220,639	295	220,344	217,191	3,154	313		560,806	50,000		
CELLULOSE			4,724	4,488		236		72	3		72		7								
XYLAN			282	268		14		4	0		4		0								
SOLUBLE SOLIDS			26,271	1,530		24,741		7,545	332		7,545		755								
ASH			466	27		438		134	6		134		134	134							
LIGNIN			20,706	19,670		1,035		316	14		316		316		316						
XYLOSE			2,675	156		2,520		768	34		768		77								
HMF	8	8	62	4		58		18	1		26		3								
FURFURAL	442	442	4,046	236		3,811		1,162	51		1,604		160								
AMMONIA (AQUEOUS)			658	625		33		10	0		10		10		10						
GLYCEROL			2,475	144		2,331		711	31		711		71								
CELL MASS			4,253	4,040		213		65	3		65		2,042		3,141						
CELLULASE			890	52		838		256	11		256		26								
ETHANOL																					
ACETALDEHYDE																					
CARBON DIOXIDE												4,279									
METHANE												3,631									
AIR																					
TOTAL	22,416	22,416	530,246	58,182		472,064		149,812	6,338		232,149	8,205	223,945	217,324	6,933	313		560,806	50,000		
Temperature, C	100	100	70	70	70	70	70	70	37		70	35	35	35	35	35		30	30	28	10
Temperature, F	212	212	158	158	158	158	158	158	99		158	95	95	95	95	95		86	86	82	50
Pressure, psig	0.005																			45	
Specific Gravity (lb/ft3 for vapor)	0.037	0.96	1.01	1.19		0.99		0.99	1.01		0.98	0.059	1.00	1.00	1.27	0.994		1.00	0.96	0.298	1.00
Flow, gpm (ft3/min for vapor)	10,016	47	1,050	98		952		303	13		473	2,299	448	436	11	1		1,124	104		

DESIGN BASIS:			Composition of Biogas:			
Solids recovery by centrifuge =	95%			Methane =	0.459	lb Methane/lb Biogas
Solids concentration in sludge =	50%	by weight		CO2 =	0.541	lb CO2/lb Biogas
Organics converted =	90%					
Biogas created =	0.8	lb Biogas/lb Organics	Water entrained with Biogas =		0.0373	lb Water/lb Biogas
Cell Mass created =	0.2	lb Cell Mass/lb Organics				
Organics converted =	100%					
Solids recovered in sludge =	100%					
Solids concentration in sludge =	50%	by weight				

STEAM PRODUCTION MATERIAL BALANCE
TABLE 4-7

BLOCK FLOW MATERIAL BALANCE. SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

AREA 700, AEROBIC REACTION AND BOILER

	Sludge to Boiler	LP Vent Gases	Biogas to Boiler	Sludge to Boiler	Boiler Fuel	Flue Gas	Steam Generated	Boiler Solids	HP Steam	LP Steam	Preheat Steam	Generator C'ndnsate	Boiler Feed Wtr	Boiler Blowdown	HP Cond	Flashed Cond	LP Cond	BFW Chemicals	Make-up Water	Feed to Deaeratn	Combstn Air
COMPONENT \ STREAM NUMBER	620	628	630	633	700	701	702	703	704	705	706	707	708	709	710	711	712	714	715	716	717
WATER	26,944	1	295	3,154	30,393		258,291		80,550	29,540	10,000	138,201	271,205	12,915	50,991	3,569	47,422		127,128	257,636	
CELLULOSE	4,488				4,488																
XYLAN	268				268																
SOLUBLE SOLIDS	1,530				1,530																
ASH	27				27																
LIGNIN	19,670			316	19,986																
XYLOSE	156				156																
HMF	4				4																
FURFURAL	236				236																
AMMONIA (AQUEOUS)	625			10	635																
GLYCEROL	144				144																
CELL MASS	4,040			3,141	7,161																
CELLULASE	52				52																
ETHANOL		103			103																
ACETALDEHYDE		414			414																
CARBON DIOXIDE			4,279		4,279																
METHANE			3,631		3,631																
AIR																					
TOTAL	58,182	518	8,205	6,620	73,526		258,291		80,550	29,540	10,000	138,201	271,205	12,915	50,991	3,569	47,422		127,128	257,638	
Temperature, C	70	37	35	35	65		460		186	147	147	49	15		186	147	147		15	69	
Temperature, F	158	99	95	95	149		860		366	297	297	121	59		366	297	297		59	157	
Pressure, psig							1100		150	50	50	89 torr			150	50	50				
Specific Gravity (lb/ft3 for vapor)	1.20	0.109	0.08	1.27	1.35		1.56		0.363	0.150	0.150	0.99	1.00		0.882	0.150	0.92		1.00	0.978	
Flow,gpm (ft3/min for vapor)	97	79	1,709	11	109		2,760		3,698	3,293	1,115	279	544		116	398	103		255	527	
Thermal Value, MM Btu/Hr	264.8	6.2	78.9																		

DESIGN BASIS:				GROSS VALUE		NET VALUE	
Enthalpy of 1100 psig Steam, 300 °F =	1420	BTU/lb	Heating Value of Cellulose =	7464	BTU/lb	6906	BTU/lb
Enthalpy of Boiler Water Inlet =	196	BTU/lb	Heating Value of Xylan =	7464	BTU/lb	7024	BTU/lb
Boiler efficiency =	85%	after boiling water	Heating Value of Sol. Solids =	5000	BTU/lb	4200	BTU/lb
Flash Steam created in 50 psig =	7%		Heating Value of Lignin =	11478	BTU/lb	10938	BTU/lb
Boiler blowdown =	5%	of water feed	Heating Value of Xylose =	6747	BTU/lb	6147	BTU/lb
			Heating Value of HMF =	12836	BTU/lb	11662	BTU/lb
			Heating Value of Furfural =	12836	BTU/lb	11662	BTU/lb
			Heating Value of Ammonia =	8822	BTU/lb	7139	BTU/lb
			Heating Value of Glycerol =	7774	BTU/lb	6991	BTU/lb
			Heating Value of Cell Mass =	7464	BTU/lb	6906	BTU/lb
			Heating Value of Cellulase =	5000	BTU/lb	4200	BTU/lb
			Heating Value of Ethanol =	12836	BTU/lb	11662	BTU/lb
			Heating Value of Acetaldehyde =	12835	BTU/lb	12017	BTU/lb
			Heating Value of Methane =	23894	BTU/lb	21800	BTU/lb

CHEMICAL & UTILITY REQUIREMENTS SUMMARY
TABLE 4-8

BLOCK FLOW MATERIAL BALANCE. SCREENING STUDY FOR SAWMILL WASTE -TO -ETHANOL STUDY

SUMMARY, UTILITIES AND RAW MATERIALS REQUIREMENTS

	LP Steam	HP Steam	Cooling Water	Chilled Water	CIP Water	Cooling Tower BD	CTW Windage	Well Wate Backwash	Well Wate Misc.	Make-up Water	Process Air	Sawdust	H2SO4	Ammonia	Nutrients	Corn Steep Liq.	Glucose	Anti-Foam	Salable CO2	Product Ethanol	Gasoline
COMPONENT \ STREAM NUMBER																					
WATER	39,540	80,550	11,231,118	424,759	50,000	303,240	179,698	10,000	10,000	463,643		83,333	27				604			166	
CELLULOSE												38,500									
XYLAN												20,000									
SOLUBLE SOLIDS												4,667									
ASH												167									
LIGNIN												20,000									
H2SO4													1,315								
AMMONIA														635							
AIR											110,240										
NUTRIENTS															21						
CORN STEEP LIQUOR																73					
GLUCOSE																	52				
ANTI-FOAM																		4			
GASOLINE																				1,119	1,119
ETHANOL																				24,082	
FUSEL OIL																				35	
CARBON DIOXIDE																			11,832		
TOTAL	39,540	80,550	11,231,118	424,759	50,000	303,240	179,698	10,000	10,000	463,643	110,240	166,667	1,342	635	21	73	656	4	11,832	25,402	1,119
Temperature, C		186	30	10	30	30	30	15	15	15	28	16	20	25			25				
Temperature, F	297	366	86	50	86	86	86	59	59	59	82	60	68	77			77				
Pressure, psig	50	150									45			130							
Specific Gravity (lb/ft3 for vapor)	0.150	0.363	1.00	1.00	0.96	1.00	0.045	1.00	1.00	1.00	0.298	20	1.84	0.60			1.02			0.789	0.731
Flow,gpm (ft3/min for vapor)	4,408	3,698	22,518	849	104	609	68,555	20	20	930	6,173	139	1	2			1			64	3
										scfm=	24498										
											24,498										

DESIGN BASIS:		
Gasoline added to denature Ethanol =	0.05	gal Gasoline/gal Ethanol
Cooling tower losses from windage =	0.3%	
Cooling tower losses from evaporation =	1.3%	
Cooling tower losses from blowdown =	2.7%	
Glucose composition as purchased =	80%	by wt.
	20%	by wt.

4.4 Process Concerns and Recommendations

In the course of carrying out this study, we have identified areas of technology that are recommended for further development to confirm system design and operating conditions for a commercial facility. These are discussed briefly below:

4.4.1 Neutralizing Base

We have used ammonia as the basis for neutralizing after acid hydrolysis, and for controlling xylose fermentation pH. Ammonia was chosen to avoid the severe fouling of heating surfaces and distillation trays that would result with lime based neutralization. NREL has expressed concern that the use of ammonia may lead to a buildup of toxic levels of ammonium ion (around 1.7 grams/liter of NH3). The material balance detailed in Tables 4-1 through 4-8 shows the ammonia buildup to be 1.4 grams/liter, which is below the expected toxic level. Nevertheless, ammonia, in conjunction with other toxins, may be a problem and should be investigated as part of an ongoing development.

4.4.2 Fermentation Temperature

Both the xylose fermentation and the SSF have recommended process temperatures of 37°C. In the case of SSF, this temperature had been selected by SERI in the prior wood chip study (SERI/TP-232-4295) as an optimum temperature that balances the needs for enzymatic hydrolysis and for yeast fermentation. Hydrolysis is favored by higher temperature (in the range of 40°C), and fermentation is favored by lower temperature (in the range of 32°C). The ability of the yeast strains to thrive at 37°C under the proposed hydrolysate environment should be demonstrated prior to commercialization. For multiple vessel continuous fermentation used in this study, it may be possible to customize the temperature in each fermenter vessel to optimize the SSF step. Belcan is not presently aware of the preferred fermentation temperature for xylose fermentation with the genetically engineered E. coli, but its viability at 37°C in wood hydrolysate should be established by testing prior to setting the commercial scale design temperature.

4.4.3 Distillation Thermal Design

We have included ethanol dehydration to achieve 199° proof ethanol from the distillation area. The system utilizes benzene as an azeotrope entraining agent for the water removal. Other methods of dehydration are also available. Thermal efficiency is achieved by operating the dehydration system at elevated pressure (about 130 psig) so that the overhead vapors from the two dehydration system columns can be used to generate steam for driving the Beer Column. In addition, the Beer Column overhead vapor is taken directly to the Rectifier, and the stripped bottom product from the Beer Column is used to preheat the incoming beer. No additional steam is required for rectification to 192° proof ethanol. Other, more elaborate methods are available to further reduce the energy for distillation, and prior to commercialization, an economic evaluation of these methods should be carried out to optimize distillation operating and capital investment costs.

4.4.4 Ethanol Dehydration

The present United States fuel ethanol market cannot use ethanol that has not been dehydrated. This is because it is blended at a 10% level with gasoline. If the water is not removed, a second liquid phase will form when blending with gasoline. In the future, as practiced in Brazil, there may be ethanol powered automobiles that run on 95% ethanol. In addition, it may be feasible to have dedicated bus or trucking fleets that are designed for ethanol fuels. If this occurs, then dehydration will not be needed.

4.4.5 Lignin Separation

Belcan recommends further investigation into the technology for separation of lignin from the spent beer. Considerable work in this area has been done recently in connection with solvent (ethanol) pulping of wood to produce wood pulp. The lignin is dissolved in hot ethanol that is subsequently distilled off, leaving water and solids that are then separated. This work has been carried out by Repap Ferrostaal, Inc., headquartered in Kimberly, Wisconsin. Initial contacts with this company have indicated that they would be willing to share this technology under appropriate agreements with NREL.

4.4.6 Lignin Slurry Firing

The optimum boiler design for lignin firing should be confirmed by testing. In addition, a more detailed evaluation of the South Point Ethanol boilers is needed to determine the modifications that would be needed to fire this slurry.

4.4.7 Continuous Fermentation Setup

Belcan has grouped the fermentation sections (xylose and cellulose SSF) into parallel trains of four fermenters each, instead of one sequential train each for xylose fermentation and cellulose SSF. It is felt that multiple parallel trains will minimize the impact of contamination or other biological upset that might completely shut down a single continuous fermentation train. However, since backmixing and short circuiting will detract from true plug flow, four fermenters may not be the optimum count for effective continuous fermentation. We recommend further study and experimental development be carried out to determine the optimum number of sequential fermenters in a single continuous fermentation train.

4.4.8 Fermenter Inoculum Percentage

The inoculum quantities for the continuous steps (xylose and SSF) are based on supplying 10% for startup of the first fermenter in each fermentation train. It is assumed that organism growth subsequent to startup will be sufficient to make up for mortality and dilution by incoming medium. Ordinarily, such sufficient growth rate is achievable, but this should be determined by actual continuous fermentation testing.

4.4.9 Water Recycle

The amount of water recycle that is feasible should be tested since its recycle causes possible toxins to build up in the system which could reduce fermentation efficiency. If water recycle is reduced, additional water makeup and effluent will be required. The overall impact on cost should not be significant.

4.4.10 Pretreatment Impregnator Reactor

The present equipment list includes a spare Impregnator/Reactor for prehydrolysis. This is because of the rugged duty imposed on this equipment. Additional testing at NREL's Process Development Unit may eliminate the need for a backup Impregnator/Reactor. This would result in a substantial cost saving.

4.4.11 Zymomomas mobilis

Ongoing research is being carried out on Zymomomas mobilis by Dr. Stephen Picataggio, et.al. at NREL. A recent report on this work was published in Science, Vol 267, January 13, 1995. Z. mobilis has been metabolically engineered to enable it to ferment xylose as well as glucose sugars. Fermentation completion times of 30 hours reported with yields reaching 95% of the theoretical for a mixed medium containing both xylose and glucose at 25 gm/liter. Longer times would likely be needed under SSF conditions. In addition, Z. mobilis is generally recognized as safe for use in animal feed. While animal feed byproduct is not anticipated at this time, E. coli may not share the same exposure safety rating as Z. mobilis and yeast. Based on these observations, Belcan believes that Z. mobilis should be further investigated as the organism of choice for sawdust (and other ligno-cellulosic) feedstocks.

4.4.12 Materials of Construction

The cost estimate is based on the use of carbon steel as the material of construction for the xylose, cellulase, and SSF fermenters and associated pumps and piping. This results in a cost saving of about $8 MM for the plant. The potential problem with carbon steel is that it may be more difficult to achieve proper sterility during CIP/CS operations. Small pits and surface irregularities in carbon steel can serve as site for difficult to remove bacterial contamination. As a countermeasure to potential infections for continuous xylose fermentation and SSF, we have included additional fermenters that will allow cleaning of the vessels periodically without having to shutdown the process.

4.5 Environmental Emissions

4.5.1 Summary

The preliminary estimates indicate that volatile organic emissions (ethanol) and particulate (sawdust) are the primary pollutants, possibly requiring the biomass to ethanol facility to be designated a major source under the Clean Air Act (depending on the final design of the emission control system).

Combustion gases (NOx, SOx and CO) and minor sources of hazardous air pollutants (acetaldehyde, BTEX) or air toxics (H2SO4, NH3) have also been identified, impacting upon the reporting requirements for the facility.

4.5.2 Terminology

BAT - Best Available Technology
BTE - Biomass To Ethanol
BTEX - Benzene, Toluene, Ethylbenzene, and Xylene
CIP - Clean In Place
CAA - Clean Air Act
CAAA - Clean Air Act Amendments
EPCRA - Emergency Planning and Community Right to know Act
HAP - Hazardous Air Pollutant
LDAR - Leak Detection And Repair
MACT - Maximum Achievable Control Technology
NAAQS - National Ambient Air Quality Standards
NESHAPS - National Emission Standard for Hazardous Air Pollutants
NPDES - National Pollution Discharge Elimination System
NSPS - New Source Performance Standards
OAC - Ohio Administrative Code
ODCS - Ozone Depleting Compounds
OEPA - Ohio EPA
PTI - Permit To Install
PSD - Prevention of Significant Deterioration
PTO - Permit To Operate
RACT - Reasonably Available Control Technology
SIP - State Implementation Plan
TCLP - Toxic Characteristic Leaching Procedure
VOC - Volatile Organic Compound

4.5.3 Background Information/Sources of Information

Regulatory Requirements

This section details key regulatory information for the BTE (Biomass to Ethanol) facility, providing background for the approach taken to estimate and compile the emissions in this report. Since South Point Ethanol (South Point, Ohio) is one of the designated sites being considered for the BTE process, federal regulatory requirements are discussed in conjunction with Ohio EPA CAA (Clean Air Act) Title V and other regulatory programs. Equivalent requirements exist for Kentucky and West Virginia, and the relevant regulations that were evaluated are listed in Appendix H.

The purpose of the next discussion is to provide a general overview of the environmental requirements. It is included to enhance the understanding of the emissions estimates and the recommended actions, which are based on some of the regulatory guidance or requirements provided herein.

Background

The CAA calls for the U.S. EPA to establish national ambient air standards that include the regulation of sources of emissions of air contaminants from stationary sources, such as industrial facilities; and from mobile sources, such as automobiles and trucks. How these sources are regulated are based on the existing air quality in the area as determined by the State of Ohio and approved by the U.S. EPA. The NAAQS (National Ambient Air Quality Standards) under the CAA and emission standards applicable to individual operations or pieces of equipment releasing air contaminants at the BTE facility are administered by the OEPA. The federally approved State Implementation Plan (SIP) issued under the Ohio Revised Code Chapters 3704 and 3745 adopts the NAAQS and contains regulatory emission standards for new and existing sources of air contaminants. The OEPA air standards for the selected location of the BTE facility will be administered through the regional offices of the OEPA.

The attainment and maintenance of the ambient air quality standards, as well as the prevention of significant deterioration of air quality (PSD), are implemented through a permit program for authorizing permits to install (PTI) and issuing permits to operate (PTO) pursuant to the Air Standards [Ohio Administrative Code (OAC) 3745-31 and OAC 3745-35]. A facility having emissions of regulated air contaminants must make a determination of applicability based on the nature of the operation and/or the rate of such emissions and apply for permits if so required. Regulated air contaminants can be criteria air pollutants (particulate, organic ozone precursor (VOC), NO×, SO×, CO or lead), hazardous air pollutants (HAPs) or air toxics. In general, a source having emissions below 100 tons per year for any single criteria air pollutant is considered minor although the major designation may be applied at lower levels if the region is considered non-attainment for the particular pollutant.

A PTI is required prior to installing a new air contaminant source or causing a modification of an air contaminant source. Air contaminants include particulates, fumes, gas, mist, smoke, vapor or odorous substances, or any combination thereof. A source is defined as any building, structure, facility, operation, installation, other physical facility, or real or personal property that emits or may emit an air contaminant (OAC 3745-15-01). The PTI can be issued, if in the OEPA Director's judgment, the source will not interfere with attainment and maintenance of the NAAQS, violate any applicable laws and employ the best available technology (BAT). A PTO is issued for a term of 3 years. Under a relatively recent rule change (OAC 3745-3502(A)(2)), sources that are exempted from PTI requirements in OAC 3745-31-03(A)(1) and (A)(2) are also exempted from PTO requirements. A PTO may place specific conditions on the operation of the source such as limitations on mass emission rates, hours of operation, monitoring, record keeping, and reporting requirements. In addition to the PTI/PTO provisions, a new general "catch-all" rule for air contaminant sources is reflected in a nuisance air pollution prohibition (OAC 3745-15-07).

A permit fee system is currently in place in all three states and CAA permit fees are expected to be assessed based on major source emission tonnage. Major or minor source designation is typically made based on the quantity of regulated pollutants (criteria, HAPs), though attainment status and other regulatory requirements can impact major source designation. Emission fees for major sources in Ohio for the 1994 reporting year were $24.05 per ton of pollutant emitted.

In addition to permit requirements, sources must comply with the federal new source performance standards (NSPS) and the national emission standards for hazardous air pollutants (NESHAP). These are incorporated by reference into the OEPA Air Quality Regulations (OAC 3724-15 through 3745-26).

Under CAAA Title III, major point and specified area sources of HAP's listed in the law must use the maximum achievable control technology (MACT) within 3 years of promulgation. The promulgation schedule runs through the year 2000 for categories of industries that have been found by the U.S. EPA to emit HAP's in harmful amounts. In terms of HAP emissions, major source is defined as one emitting more than 10 tons per year of any one HAP or an aggregate of 25 tons or more of a combination of HAP's. The hazardous air pollutant (HAP) emissions from the BTE facility will be regulated by a Maximum Achievable Control Technology (MACT) in the year 2000 under the U.S. EPA's proposed schedule. No HAP limitations have been identified for the proposed BTE facility.

Under Title V, each major source of air contaminants must obtain a single federally enforceable operating permit containing all emission, monitoring and compliance requirements applicable to the source. Emissions of ozone depleting compounds (ODCS) must also be reported at such major sources. Major sources are defined for Title V as ***any source subject to PSD requirements, any source subject to non-attainment area control requirements, any source with over 100 tons per year (tpy) of emissions of any air pollutant, or a regulated HAP's major source.***

Relative to the BTE process, the facility will most likely qualify as a major source under Title V because the facility would emit over 100 tpy of a single criteria air pollutant, primarily ethanol (VOCs). Dust from feedstock handling may also exceed 100 tpy. The emissions come from two different types of air contaminant sources at the BTE facility. These include point emission sources, which discharge through discrete stacks or vents to the outside air, and fugitive emission sources, which discharge to the air without going through a chimney, vent or other discrete functionally equivalent opening. Both types of emissions are regulated by the OEPA. In the following discussion, the nature and quantities of these air emissions are discussed in detail for each of the BTE process systems , along with minor wastewater discharges and solid waste disposals expected from the proposed facility.

4.5.4 Environmental Emission Considerations

An evaluation of the Biomass-To-Ethanol (BTE) process and its potential emissions (point source, fugitive and accidental occurrence) was conducted for each of the BTE process systems, consistent with those systems identified in the Solar Energy Research Institute (SERI) "Technical and Economic Analysis of an Enzymatic Hydrolysis Based Ethanol Plant" (June 1991). These included:

- Raw material handling
- Pretreatment/Prehydrolysis
- Neutralization
- Xylose fermentation
- Cellulase production
- Simultaneous Saccharification and Fermentation (SSF)
- Distillation, Rectification, and Dehydration
- Centrifugation
- Tank Storage
- Utilities
- Environmental Systems

Each system's influent and effluent streams were evaluated for the presence of potential criteria, hazardous air pollutants (HAP's) and toxic air pollutants, as defined by the Clean Air Act (CAA), its recent amendments, and the relevant state (OH, KY and WV) statutes. Air emissions were quantified for those systems with point or fugitive sources that discharged directly to the environment, and hazardous constituents were identified for those contained processes that would need to be part of an active Leak Detection and Repair (LDAR) program to prevent HAP or toxic pollutant emissions.

Wastewater discharges from the water treatment process were compared to the warm water aquatic habitat and safe drinking water quality standards to identify the contaminants that would need to be carefully controlled from the BTE process to ensure the National (and State) Pollution Discharge Elimination System (NPDES) program requirements were met. Considering the current design described in the 1991 SERI report, these discharges can be controlled with the wastewater treatment system that has been preliminarily designed. Final design of the storm water and sewer drainage system for the BTE facility will incorporate the NPDES requirements, and the industrial wastewater generated is expected to meet the water quality requirements for discharge to the Ohio River or other tributary.

Uncombusted waste from the boiler is the only solid waste that requires disposal, and it is anticipated that this material will be classified as RCRA non-hazardous waste, exempt from RCRA land disposal restrictions, based on a preliminary review of the boiler influent constituents and concentrations. Toxic Characteristic Leaching Procedure (TCLP) analyses will need to be performed on the boiler ash to confirm that residual contaminants such as acetaldehyde are not present in characteristically hazardous concentrations.

Table 4-10 contains a general overview of the systems evaluated, the potential pollutants or hazardous constituents, the discharge points, and for those systems or processes discharging directly to the environment, the emission estimating methodology and quantity of emissions (lbs/ton feedstock). Appendix A contains the calculations and key input parameters used to estimate the actual emissions. This information and details for each of the systems are discussed in the following sections.

Raw Material Handling

As Table 4-10 indicates, the principal pollution concern with the unloading, storage, handling and material transport of the sawdust feedstock is the suspended particulate matter that will be generated as a result of these raw material handling operations. Very little environmental information is available regarding these estimated or actual fugitive emissions, but the woodworking waste (sawdust, shavings, sanderdust, etc.) collection industry has documented (U.S. EPA AP-42 Emission Factors, Section 10.4) that 1.0 lb particulate per ton woodwaste and 2.0 lb particulate per ton woodwaste can be expected during storage and loading in woodwaste bins. Using these factors, at an estimated 2,000 tpd loading during BTE process operation and a storage pile or "bin" of 8 tons (4 day supply) maintained year round, particulate emissions can be estimated to be 2.04 lb (wood) particulate per ton of feedstock. Details of the calculations are provided in Appendix A. With such a large volume of sawdust being handled each year (666,000 tons), dust emission would be 666 tpy. Therefore the BTE facility would be considered a major source of particulate emissions under the CAA Title V program in either Ohio, Kentucky or West Virginia. We believe these figures are very conservative. However, until the final design of the raw material handling system is completed, particle size characteristics of the actual feedstock are identified, site location/meteorology is determined, and the moisture variability of the feedstock from the various sawdust suppliers is understood, additional efforts to detail the particulate emissions would be premature.

Though environmental literature has not provided information regarding fugitive organic emissions from sawdust or woodwaste piles, eight ton piles of sawdust or woodwaste material can also result in significant VOC emissions. These emissions should be quantified when the feedstock characteristics of the different suppliers are known.

Pretreatment/Prehydrolysis

After the sawdust feedstock is stockpiled, it is conveyed to a contained system of reactors for prehydrolysis of the xylan to xylose with dilute Sulfuric Acid (H2SO4). The Impregnation reactors, Prehydrolysis reactors, Blowdown tank, Sulfuric acid tank (T-201) and associated pumps are an enclosed system of pressurized vessels and connective piping. Though the sulfuric acid manufacturing industry has identified uncontrolled acid mist and small quantities of sulfur oxide emissions from leaks in process equipment and storage tank vents, H2SO4 emissions are considered neglible due to the low concentration of acid (0.85% by weight) being sprayed in the Impregnator reactor and the relatively small amount of acid being stored in the process area. Upon final design of the system, a systematic review of the potential emission points (flanges, pumps, breather vent pressure setpoint) should be conducted to verify there are no emissions, since H2SO4 is considered an extremely hazardous substance under the Emergency Planning & Community Right To Know Act (EPCRA), with a relatively low threshold reporting quantity.

Neutralization

When the acid hydrolyzed slurry of xylose, cellulose and lignin is transferred from the Blowdown Tank to the Neutralization tank (T-206), ammonia is used to neutralize the acid slurry. T-206 is vented to the Low Pressure Vent (LPV) system, and the ammonia quickly reacts in solution, resulting in negligible emissions from this part of the process. The LPV system is discussed further in the section on Environmental Systems.

Xylose Fermentation System (XFS)

Once the acid hydrolyzate is neutralized, 98% of the stream is sent to the Xylose Fermentation System (XFS) for conversion of the xylose to ethanol with E. coli. Approximately 1% of this XFS stream is diverted to the seed fermenters for developing E. coli cultures, and 99% of the stream is sent to the fermenters for actual conversion of the xylose to ethanol.

Ammonia (NH3) is added to the xylose fermenters to regulate pH, and developed E. coli cultures are also transferred from the Seed hold tank to the fermenters. During the xylose anaerobic fermentation, the fermenters are vented to the atmosphere. Since each fermenter is at atmospheric pressure, the possibility of E. coli becoming entrained is remote, and conversations with the developer of the E. coli strain (Dr. Len Ingram, University of Florida, Gainesville) have confirmed that it is non-pathogenic. Trace amounts of NH3 may be vented, but concentrations are considered negligible because an acid pH is maintained. Ethanol and CO2 will be discharged to the atmosphere from the vent point source, and calculations in Attachment 1 detail that 224 tpy of ethanol will be released to the atmosphere from the vent. As a volatile organic compound (VOC) that is a precursor to ozone, New Source Performance Standards (NSPS) may dictate emission controls, especially if the selected site is in an Ozone non-attainment county.

The seed fermenters that receive 1% of the XFS stream are part of a contained system in which E. coli inoculum flows under slight (air) pressure to the xylose fermenters. No VOCs are released to the atmosphere.

The remaining 2% of the neutralized hydrolyzate that is not channeled to the XFS is transferred to the Cellulase Production area for generation of the cellulase enzyme from a mixture of the neutralized hydrozylate, fungi (T. reesei), corn steep liquor, NH3, and antifoam agent.

Cellulase Production

When the small stream of neutralized hydrolyzate is used to produce Cellulase enzyme, there is no discharge to the environment of any of the potential pollutants listed in Table 4-10. The minor amounts of ammonia that may be required for the seed inoculum quickly react in solution and are not expected to vent from the cellulase seed fermenters. The cellulase fermenters involve the use of small amounts of aqueous ammonia (10 lb/h), which is already in solution and therefore not volatile during mixing. As a result of the change from lime to NH3 during neutralization, additional non-aqueous NH3 would not be needed during cellulase fermentation, and would not be a potential source of vent emissions.

Simultaneous Saccharification and Fermentation (SSF)

Upon production of cellulase, the hydrolysis of xylan to xylose, and the subsequent fermentation of xylose to ethanol, the unreacted cellulose fraction of the biomass stream is converted to glucose, and then ethanol (by cellulase and yeast respectively) in the SSF reactors. The key compound or material components of the SSF influent stream are noted in Table 4-10, but the SSF process is a contained system, discharging offgas to the environment only after a condenser (SSF vent condenser) and scrubber (CO2 vent scrubber) have recovered most of the entrained ethanol. As the following discussion details, volatile organic compound (VOC) emissions are the chief environmental concern.

As with xylose fermentation, VOC emissions, in the form of ethanol evaporative losses, are the only regulated pollutants with direct discharge to the environment. The average concentration of ethanol in the SSF reactors is higher (~5.0% w in effluent) than in the xylose fermenters (~2.0% w in the effluent), and as a result, the concentration of ethanol is high enough in the offgas to warrant recovery with the SSF vent condenser (see Figure 4-9). The chilled water condenser that removes ethanol from the SSF reactor exhaust (TT-525) will remove about 30% of the ethanol from the SSF vent stream. Approximately 3/4 of the uncondensed SSF vent stream will then pass through the CO2 scrubber, where the CO2 will be "scrubbed" to make it saleable. Due to the higher concentration and the greater number of SSF reactors, this part of the process has a much higher exhaust flow rate (4X that of xylose fermenters), and CO2 scrubbing with ethanol recovery has both financial and environmental benefits. Still, ethanol losses in the unscrubbed CO2 stream vented after the SSF condenser account for 128 tpy in VOC emissions. (See Appendix A calculations).

Condensed ethanol from the SSF condenser is collected and combined with the SSF product, which is pumped to distillation for purification. The remainder of the SSF process is aerobic (Seed fermenters and Seed hold tanks) and under slight positive pressure, but contained, and discharges only into the SSF reactors (barring any accidental spills or equipment leaks). The only exception to this is the CIP and Chemical sterilization system that is described in a later section.

Distillation, Rectification, and Dehydration

From the last fermenter in the SSF system, the relatively weak ethanol product (5.0% by weight) is pumped to the Ethanol Recovery System for purification to 99.4% by weight. The ethanol product is pumped to one of two ethanol product tanks in the tank storage area where some vented emissions occur. The only "exhaust" points from this part of the system involve vents to:

- Low Pressure Vent (LPV) system from the Degasser drum condenser (Beer Distillation System)
- Low Pressure Vent from the Rectification Column Vent Condenser
- Vent to atmosphere from the Fusel Oil Decanter
- Vent to atmosphere from the Anhydrous Column Vent Condenser

As summarized in the discussion of the Environmental Systems, the LPV system has a number of vented vapor or gas streams, which are drawn into the LPV knockout drum by the LP vent blower. Entrained liquid is removed there and pumped to the wastewater treatment system. The LP vent blower discharges into the boiler, where the acetaldehyde and ethanol from rectification are combusted to organic constituents and released in trace amounts as part of the boiler exhaust gases. The Rectification Column vent condenser exhaust represents the only significant (> trace contaminants) source of air emissions from this part of the system. The exhaust comprises < 1% of the boiler fuel, which is primarily solid waste (lignin from centrifuges, lignin/cell mass from WWT clarifier) and methane gas (from the anaerobic digester). If the potential pollutants are measurable from this part of the BTE process they are in trace concentrations in the combustion gases and wastewater discharge emissions coming from the boiler and water treatment facility respectively.

The fusel oils removed from the Rectification column have very low vapor pressures (< 5 mm Hg @ ambient conditions) and are not expected to contribute to the organic compound emissions via the vent from the Fusel oil decanter. However, ethanol is removed from the column with the fusel oils, and though condensed, some ethanol will be vented to the atmosphere. The extent of this emission should be further evaluated, and, if necessary, routed to the LP Vent System.

Centrifugation Or Lignin Separation

The streams from the bottom of the Beer Column and the sludge from the recycled water tank are centrifuged to remove lignin as fuel for the boiler. Liquid overflows to the Recycled water tank and centrifuged solids are combusted to ash in the boiler. No emission points or fugitive evaporative emissions are noted, as the recycled water is contained and pumped to one of three other systems: to prehydrolysis, to the seed fermenters (as a nutrient base) or to wastewater treatment.

Tank Storage

The following storage tanks contain volatile or semivolatile liquids that have the potential for VOC emissions or toxic air pollutant emissions as a result of normal breathing or "working" (loading/unloading) losses:

- Two ethanol product storage tanks (T-701A, T-701B)
- Gasoline (T-700)
- Sulfuric Acid storage tank (T-703)
- Diesel Fuel storage tank (T-708)
- Ammonia (T-706A/B/C/D)
- Benzene storage tank (T-705)

Equations from the USEPA Tanks Program (AP-42, Section 12.3, "Storage of Organic Liquids", 4th ed.) developed by the American Petroleum Institute were used to estimate the emissions. Supporting calculations are provided in Appendix A and Table 4-10 summarizes the expected emissions from storing materials for/from the production of 87.4 gal of ethanol per ton of (dry) feedstock.

Assuming 333 operating days (666,000 tons of "wet" feedstock/year), ethanol breathing and working losses from the two 500,000 gallon ethanol product storage tanks were substantial. With nearly 1.5 MM gallons handled each year, ethanol evaporative losses amount to more than 21 tpy of VOC emissions. This translates into an average emission rate of .06 lb ethanol/ton of "as is" (wet) feedstock for the 2000 tpd facility.

Standing storage and filling losses from the 88,000 gasoline storage tank also yield considerable organic emissions (BTEX compounds included) resulting in more than 17 tpy of vapor emissions during storage and filling.

Estimated emissions from the much smaller Diesel and benzene storage tank are considered insignificant because of the size, low material usage and/or containment control. With tanks designed to New Source Performance Standards, emissions from the Ammonia and Sulfuric Acid storage tanks will also be insignificant, and are estimated to be negligible or present in trace concentrations if ambient monitoring is performed in the tank storage area, as listed in Table 4-10.

Utilities

A number of different systems are required to provide power, steam, heat, process water, boiler feed water, cooling capacity, chilled water, process/plant air, sterile air and sterile equipment. These include:

- Boiler system and Turbogenerator system
- Boiler Feed Water (BFW) system
- Process Water system
- Cooling Water system
- Plant & Instrument Air system`
- Chilled Water system
- Clean In Place & Sterilization system

A review of each of these systems for potential environmental emission points indicates that most of the systems are self contained or discharge/vent into other contained processes. The notable exceptions are the Boiler system, BFW system, Cooling Water system, and depending upon final design, possibly the CIP & Sterilization system. Only the combustion gases in the boiler exhaust are considered significant sources of emissions and warrant quantitative estimates at this point in the design. Other emission points (BFW system deaerator, Cooling tower) have the potential for releases of minor amounts of HAP's or VOC's such as ethanol, but quantitative estimates are not necessary or practical to assess the environmental characteristics of the site.

Emission estimates for the boiler are based on a complex solid, liquid and gaseous fuel stock from the Lignin centrifuge (solids), aerobic digester (solids), Rectification Column (fusel oils), anaerobic digestion (biogas), and Low Pressure Vent system (offgas from Knockout drum). This diverse fuel stream is similar to the type of woodwaste burned in pulp and paper mill boilers, and emission factors for woodwaste boilers (AP-42, Section 1.6 "Wood Waste Combustion in Boilers") were used to estimate the criteria pollutant emissions (CO, SO2, Organic Compounds, PM, NO2, etc.) from combustion. Appendix A details the emission factors and calculations used to identify the emissions from a 400 MMBtu/hr boiler that burns lignin, cellulose (~15%) and small amounts of methane as fuel. Emission factors for natural gas fired industrial boilers (AP-42, Section 1.4 "Natural Gas Combustion) were also used to calculate the quantity combustion gases generated from burning 3631 pounds of methane per hour.

Most new boiler installations utilizing wood waste material as fuel have employed electrostatic precipitators as the Best Available Control Technology (BACT) for particulate control, and with this type of air pollution control, nitrous oxide (125 tpy) was the only criteria pollutant estimated to exceed 100 tpy. If mechanical collectors (cyclones) or some less efficient air pollution control equipment is installed, particulate emissions could exceed 100 tpy causing the facility to be considered a major source for particulate for the boiler emissions alone. Table 4-10 and Appendix A detail the calculated emissions, assuming the BTE process itself provides all of the necessary fuel feedstock. More detailed technical information about the feed drying system, fuel burning system and fuel feeding system is needed to provide more accurate emission estimates.

Environmental Systems

As Table 4-10 illustrates, the environmental systems associated with the BTE process can be further divided into the wastewater treatment system, anaerobic digestion system, aerobic digestion system and low pressure vent system. Each of these systems was designed to remove or degrade potential organic contaminants or pollutants from vented air, condensed process vapor or process water. Of the four subsystems, only anaerobic digestion (offgas burner) and aerobic digestion (biotreater) have direct discharges to the environment, as the rest of the effluent is directed to the process water tank, the boiler (as fuel) or recirculated to some part of the environmental system. Emissions from the offgas burner are accounted for in the methane combustion gases detailed in the boiler emission estimate. Some fugitive organic emissions can be expected from the biotreater. Depending upon the air emission control system in place and the rate of oxidation, air emissions from the degradation of the remaining soluble solids, xylose, furfural and glycerol can be significant. For this preliminary analysis, emissions during aeration will be considered negligible.

Wastewater discharges to surface water or a POTW system are not referenced in the process flow sheets provided in the 1991 SERI technical report ("Technical and Economic Analysis of an Enzymatic Hydrolysis Based Ethanol Plant). Evaporative losses from the Cooling tower, from the boiler feed drying system, and from fugitive process emissions account for the only wastewater discharge from the self contained BTE process. However, stormwater collection systems and drainage systems will invariably collect some process water, and of the 217,000 lb/h of water directed to the cooling tower from WWT, much will require discharge from the facility to surface water or a POTW system in the vicinity of the plant. Permits for discharge to the POTW are typically regulated by local ordinances and surface water discharge is controlled by the state or regional (ORSANCO) agency. There is no reason to suspect that potential pollutants would be present in concentrations high enough to prevent discharge to the Ohio River or a tributary, based on the neutralization processes and WWT processes planned for the BTE site.

Boiler ash is the primary solid waste generated from the process, though sawdust screening, cleaning operations, centrifuge operations and daily refuse will provide unspecified quantities that require offsite landfill disposal. It is reasonable to assume that the boiler ash will be non-hazardous material that can be disposed of as solid waste. A preliminary review of the system does not indicate that the material would be considered characteristically hazardous, or judged hazardous based on the RCRA "contained in" rule (based on the component materials in the BTE process), but samples of the ash would need to analyzed for toxic constituents before that determination could be made. In either case, the disposal costs and requirements for hazardous waste and non-hazardous waste do not vary appreciably from state to state.

4.5.6 Summary of Emissions

As Table 4-10 summarizes, an estimated 421 tpy of organic compounds (primarily ethanol) would be released to the air based on current design. Since emissions are greater than 100 tons/year the BTE facility would be considered a major source of organic compound emissions. BTEX emissions are included in this total, but are not expected to exceed 10 tpy for benzene, or 25 tpy for total HAPs. Recovery of some of the ethanol emissions has been achieved during CO2 processing and recovery.

Estimated particulate air emissions are also considerable (nearly 700 tons). It is expected that the conservative estimate of sawdust emissions from the sawdust pile can be further refined/reduced. Emissions below 100 tpy are possible if wetter feedstock or contained stockpiles are deemed economically feasible during final design. Also, construction of a full scale commercial facility at a location such as SPE, where 600 acres of property provide ample settling area for fugitive dust emissions from the sawdust pile, will reduce offsite emissions considerably.

Solid waste in the form of boiler ash will require solid waste disposal, and is not suspected to contain hazardous constituents that would trigger RCRA hazardous requirements. Assuming 1% of the solid fuel fed to the boiler is disposed of as ash, approximately 1400 tpy of solid waste will need to be disposed of at a sanitary landfill (contingent upon TCLP analyses).

Wastewater discharges to the Ohio River or other surface water tributary can be expected to meet warm water aquatic habitat standards for surface water discharge based on current design. Clarifier sizing, neutralization processes, centrifuges and WWT filtration processes will need to be carefully designed and controlled at startup to meet these water quality standards, or discharge to a local POTW may be required.

TABLE 4-10: SUMMARY OF ENVIRONMENTAL EMISSIONS

EMISSION SOURCES (Area)	POTENTIAL EMISSIONS	EXHAUST/DISCHARGE POINT	ESTIMATING METHODOLOGY	ACTUAL (ESTIMATED) EMISSIONS (lb/ton feed)							
				OC	Particulate	NOx	CO	SOx	NH3	Benzene	Acetaldehyde
Sawdust handling (100)	Fugitive particulate (wood)	**Atmosphere** & Prehydrolysis	AP-42 EF for wood handling		2.04						
Prehydrolysis/Neutralization (200)	Ammonia, H2SO4		Engineering judgement								
Neutralization Reaction tank (T-206)	NH3, H2SO4	LPV system, Xylose & Cellu ferment	Trace combustion products from boiler								
Fermenters (300, 400, 500)											
Xylose fermentation (Area 300)	CO2, Ethanol, NH3, E. Coli										
Xylose fermenters (FM-303A-I)	CO2 plus entrained ethanol, etc.	**Atmosphere** & SSF Reactors	Mat'l balance & ind/research models	0.7							
Seed fermenters (FM-305-309)	E. Coli	**Atmosphere** & Xylose fermenters	Engr. judgement-negligible emissions								
Cellulase production (Area 400)	NH3, Fungi (T. Reesei), corn oil										
Cellulase fermenters (FM-400A-C)	NH3, fungi, corn oil	**Atmosphere** & Cellulase hold tk	Engr. judgement-negligible emissions								
Seed fermenters (FM-401-404A/B)	NH3, fungi	**Atmosphere** & Cellulase fermenters	Engr. judgement-negligible emissions								
Media Prep tank (T-400)	Corn oil/liquor	**LPV system** & Cellulase fermenters	Negligible-part of boiler combust prod								
SSF Reactor system (Area 500)	CO2, Ethanol, yeast, E.Coli, T.rees										
Seed fermenters (6)-FM 501-506 A/B	CO2 plus entrained mat'l	**Atmosphere** & SSF Reactors	Engr. judgement-negligible emissions								
SSF Reactors (18)-FM 500A-R	All of the above	**Atmosphere** & Vent Condenser	Mat'l balance & ind/research models	0.408							
SSF Vent Condenser (TT-525)	CO2 plus entrained/non-con ethanol	Distillation & CO2 scrubber	Mat'l balance & ind/research models								
CO2 Scrubber (AS-501)	CO2 plus entrained/non-con ethanol	Distillation & CO2 sales	Mat'l balance & ind/research models								
Ethanol Recovery/Distill & Dehyd (600)											
Distillation (600)	Ethanol, Acetaldehyde										
Degasser drum (T-601)	Ethanol, Acetaldehyde	Condenser (TT-602) & Beer Column									
Degasser condenser (TT-602)	Trace ethanol, acetaldehyde	**Atmosphere**	Engr. judgement & mat'l balance	Trace							Trace
Rectifier Column (AS-602)	Ethanol	Condensers (610, 611) & Beer Col.									
Rectifier Vent Condenser (TT-611)	Ethanol, Acetaldehyde	LPV system, ultimately the boiler									
Fusel oil decanter (T-603)	Trace amyl, isoamyl & propyl alcoh	**Atmosphere**, boiler & RC	Low vapor pressure-negligible								
Dehydration (600)	Ethanol, Benzene										
Anhydrous Column (AS-603)	Ethanol, Benzene	Condensers (TT-604, 605, 606)									
Anhydrous Vent Condenser (TT-605)	Trace Ethanol, Benzene	**Atmosphere**	Engr. judgement & mat'l balance	Trace						Trace	
Storage Tanks (700)			EPA Tanks program								
Gasoline tank (T-710)	VOCs, BTEX	**Atmosphere** (filling, breathing)	EPA Tanks program-organic liquids	0.053							
Ethanol tanks (T-701 A/B)	Ethanol	**Atmosphere** (filling, breathing)	EPA Tanks program-organic liquids	0.0637							
Ammonia storage tanks (T-706 A/B)	NH3	Contained, pressurized vessel	Engr. judgement								
Sulfuric Acid Storage tank (T-703)	H2SO4	**Atmosphere** (filling)	Contained system-negligible								
Glucose Storage tank (T-702)	Glucose	Negligible	N/A								
Corn Oil/antifoam (T-707)	Negligible	Negligible	N/A								
Diesel Fuel (T-708)	VOCs, BTEX	**Atmosphere** (filling)	Engr. judgement	Trace							
Benzene storage tank (T-705)	Trace benzene	Contained, pressurized vessel	Engr. judgement							Trace	
Corn Steep liquor tank (T-720)	Corn liquor	Negligible	N/A								
Utilities											
Boilers-feed (900)	TSP, NOx, SOx, OCs, CO, Acetald	**Atmosphere**	Wood waste fired boilers, AP-42 1.6	0.04	0.039	0.374	0.1375	0.002			Trace
Lignin Centrifuge solids (beer column)	Lignin										
Aerobic centrifuge solids (from WWT)	Lignin, cell mass										
Offgas from anaerobic digestion (CH4)	Methane										
Vapor/offgas from LPV K.O. drum	LPV contaminants										
BFW System											
Deaerator (GV-906)	NH3	**Atmosphere**	Engr. judgement						Trace		
Cooling Water System											
Cooling Tower (GT-912)	Process water contaminants	**Atmosphere**	Engr. judgement	Trace							
CIP and chemical sterilization											
Sterilization tank (T-960)	Sterilization chemicals	**Atmosphere** at dump station-TBD	TBD based on final process design	Trace							
Cleaning tank (T-961)	Cleaning chemicals	**Atmosphere** at dump station-TBD	TBD based on final process design	Trace							

TABLE 4-10: SUMMARY OF ENVIRONMENTAL EMISSIONS

EMISSION SOURCES (Area)	POTENTIAL EMISSIONS	EXHAUST/DISCHARGE POINT	ESTIMATING METHODOLOGY	ACTUAL (ESTIMATED) EMISSIONS (lb/ton feed)							
				OC	Particulate	NOx	CO	SOx	NH3	Benzene	Acetaldehyde
ENVIRONMENTAL SYSTEMS											
Wastewater Treatment	Furfural, ethanol, organics, solids	**Surface water (Ohio, tributary)**	Wastewater discharge mat'l balance	Trace							
Anaerobic digestion	Methane, Combustion gases	Boilers (HB-901A/B) or Offgas burn									
Offgas burner (GO-806)	Combustion gases	**Atmosphere**-see boiler estimate	EPA EF for gas fired boilers								
Aerobic digestion	Organics										
Biotreater (T-807) w/ aerators	Organics and clarified liquid	**Atmosphere** and secondary clarifier	TBD based on ventilation system	Trace							
Solid Waste Disposal											
Boiler ash	Trace organics	**Solid Waste landfill**	w/ 1% uncombusted solids, ~1400 tpy	Trace							
Wastewater Treatment	NONE-solids burned in boiler										
			TOTAL EMISSION RATES	1.2647	2.079	0.374	0.1375	0.002			
			TOTAL ANNUAL EMISSIONS (tons)	421.1451	692.307	124.542	45.7875	0.666			
			based on 2,000 tpd feed								

4.6 Site Area and Layout

4.6.1 *Summary*

A preliminary process layout (Fig. 4-17) has been developed for the site. This layout will be used as a guide when evaluating potential sites and adjustments will be made if appropriate to meet specific dimensions, road and rail access, water source and discharge points, and other local factors. These factors are discussed under civil engineering factors. The overall dimensions include about 50 acres.

The feed stock is delivered by rail and truck at the northeast corner of the site and sent to a sawdust pile having a storage capacity of 4 to 10 days. The material flow is west to Prehydrolysis and then into fermentation, making a U-turn and flowing east to Distillation. The spent beer from Distillation is transferred to the Centrifugation area that is placed near the Utilities area to minimize the transfer distance for the solids sludge to the boiler. The control room, laboratory, maintenance and warehousing are centrally located to the process and utilities areas. Cooling towers and waste treatment are located on the south east side of the site which will generally be on the downwind side.

4.6.2 *Site Considerations*

The plant layout as presented is a generic layout on an "even" site. Adjustments can be made as appropriate for potential sites.

The factors and resources that are necessary for the operation of the plant, their availability, how they enter the site combined with the topography of the land and the surrounding area will all have an effect on the eventual plant layout and operation.

Some of the factors that will affect the site selection and layout include but are not limited to the following:

- Topography of the land
- Geotechnical characteristics of the soil
- Availability, capacity and overall conditions of the surrounding roads and highways plus their connections to the interstate highway system
- Availability, capacity and overall conditions of the surrounding rail transport system
- Systems required to handle, to treat and to dispose of waste water and solid waste
- Environmental requirements on all the items listed herein
- Availability of utilities to include water, electrical power, natural gas, sewers, etc.
- Review of all applicable building codes, zoning codes and other local, state, and federal codes that will affect the plant construction
- Type, size and function of the buildings, structures, raw and finished materials areas, etc. and their interaction with each other

4.6.3 *General*

The topography of the land will affect the plant layout in several ways. In a positive light, a sloping site may assist in the development of the sewer systems for storm, process and sanitary sewers. In another light, a sloping site can complicate the layout, cost and design of the buildings, roads, railroads, etc. Also in the tri-state area being considered, snow and ice handling will add cost to the overall plant operations. Projections for buffer zones and future plant expansions need to be considered.

The geotechnical characteristics will have a very basic and major impact on the plant. The effects will include: type of building and structure foundations required, design of the roads and long-term maintenance requirements, and other concerns with overall care of the plant site.

The availability of utilities to the site may be one of the more critical items and one having higher initial costs and greater effects over the long-term life of the plant.

The environmental requirements of all the listed items will be considered. This consideration will include those requirements currently in force and those estimated that may be in force in the future.

The buildings, structures, raw and finished materials areas, etc. will have a major effect on the site selection. These buildings and areas and their interaction will determine the minimums required for the site.

In terms of site resource requirements, certain criteria are considered key for selecting a proper site. One is a reliable power grid and electric utility structure that can accept the export electric power as well as provide backup power to the plant during maintenance periods or other outages.

Other key requirements are a reliable source of suitable water for makeup to the plant systems and a suitable body of water to serve as a receptor of the plant's treated waste water. In addition, the air quality at the site must be such that contaminants are not present which could adversely affect the various fermentation organisms.

Other utility and chemical requirements can be readily met by any site that has the major rail and highway access that will be necessary for receipt of the sawdust feedstock and for shipment of the ethanol product.

The final selection of the plant site hasd involve the evaluation of all the above listed items. The evaluation has included both initial and long-term costs. Other intangible items such as community acceptance, available labor force and existing and potential uses of the surrounding areas were also taken into consideraton.

4.7 Utility and Chemical Requirements

4.7.1 *Summary*

Utility Requirements:

Utilities Summary

Boiler Fuel:		
Solids By-Product:	35,226	lbs/hr
Heating Value (Net)	9,175	Btu/lb
Thermal Input	323	MM Btu/hr
Bio-Gas (Methane):	3,627	lb/hr
Heating Value (Net)	21,800	Btu/lb
Thermal Input	79	MM Btu/hr
Water Evaporation:	30	MM Btu/hr
Boiler Input:	372	MM Btu/hr
Boiler Output:		
Boiler Efficiency (after water evaporation)	85.0%	
Steam Conditions	1,100	psig
	860° F (300° F superheat)	
Steam Rate	258,700	lb/hr
Turbogenerator:		
50 psig Extraction	39,500	lb/hr
150 psig Extraction	80,500	lb/hr
Steam to Turbogenerator condenser	138,600	lb/hr
Power Generated	21.8	MW
Power Consumed	6.4	MW
Power Exported	15.4	MW
Well Water	930	gpm
Cooling Water (86° F)	22,600	gpm
Chilled Water (50° F)	850	gpm
Compressed Air (82° F)	24,500	scfm

4.7.2 *Chemical Requirements:*

Chemicals required for the facility include the following. As stated above, none of these should be difficult to maintain in supply for a site having good rail and highway access.

• Sulfuric acid	5,370	tons/yr
• Ammonia	2,540	tons/yr
• Corn Steep liquor	290	tons/yr
• Glucose	260	tons/yr
• Fermentation nutrients	84	tons/yr
• Antifoam	17	tons/yr
• Caustic Soda & CIP chemicals	$50,000	
• Gasoline	1.5	MM gal/yr
• Diesel fuel		
• Boiler chemicals	$124,000	
• Cooling Tower chemicals	$486,000	

4.7.3 *Assumptions*

Key assumptions used in developing these requirements are listed below:

- Incoming sawdust at 50% moisture.
- The steam input to distillation has been minimized using the overhead vapors from the Beer Column to provide boilup for the Rectifier. Thermal energy is recovered from ethanol dehydration to supply part of the steam for beer stripping.
- Fermentation temperatures are maintained at 37° C by use of cooling tower water.
- Water makeup to the process is from direct steam injection for acid hydrolysis and distillation and from recycle of water from stillage centrifugation.
- Cooling tower makeup is from treated waste water.
- Boiler makeup is from steam condensate return and fresh treated makeup water.
- CIP water makeup is from treated well water.
- Ammonia is acceptable for process neutralization.
- Power turbine efficiency is 78.5 %, which results in the following steam rates for power generation:
    - 20.17 lb/kW-hr for 150 psig extraction steam.
    - 15.43 lb/kW-hr for 50 psig extraction steam.
    - 9.05 lb/kW-hr for vacuum condensed steam
- Power consumption equals 75% of connected loads that are normally in use.

4.8 Special Transportation

4.8.1 *Summary*

Transportation of the raw material to the plant site will be by rail and truck.

Approximately 450,000 green tons per year, 65% of the plant's raw material needs will be met by trucks. Trucks will haul raw material to the site from a radius of 100 miles at a transportation cost of $1.50 per loaded truck per mile. Rates per mile will be higher for closer distances and slightly less for greater distances. Approximately 50% of the total amount of sawdust generated by the primary wood industries (600,000 green tons) is located within a 100 mile radius of the South Point Ethanol plant. This fact would most likely hold true for any plant site established, in that the plant site would be located close to the raw material source to minimize shipping distances and potential problems caused by shipping. This potential amount represents 83% of what is required for a 2,000 ton per day operation.

Where rail is used, railroad cars will be supplied to the largest producers of sawdust on their siding and sent to a switch yard for rail car transportation to the plant site. Demurrage costs for railroad cars hauling sawdust are $20 per day for the first four (4) days, $30 per day for the next three (3) days and $60 per day thereafter. In cases where the demurrage is projected to be greater than the cost of trucking and loading a combination of truck and rail will be used. A truck will be sent to the yards of the smaller suppliers to pick up their residue and transport it to a marshaling yard where it will be unloaded and then reloaded into rail cars for long distance shipping.

Shipping of sawdust by barges was briefly considered and abandoned as economically unfeasible due to the remoteness of the large sawmills to the waterways as well as the loading, unloading and capital facility costs which would be entailed.

4.8.2 *Assumptions*

General

- "Wet-side" processing has indicated that the material should be delivered to the plant in as dry a condition as possible; i.e., little or no water should be added, except for dust control, etc. Most of the processing water will be recycled from downstream process steps, with water added as needed to replenish or refresh the process.
- The SERI study for hardwood chips used a water flume to separate foreign materials. This is not practical for sawdust due to its capacity to absorb large amounts of water. We assume it is not feasible or practical to test every incoming load for relevant factors such as composition, moisture content, or yield content. A visual inspection should be maintained.
- Dumped material will be loaded via short drag link conveyors to a belt conveyor. The convey rate of the incoming material will be several times the plant utilization rate, to permit speedy offloading at delivery. This conveyor will carry the material over to a storage pile.
- The yard will have ample provision for staging and shuffling rail cars. A car pusher/locator or a small switching locomotive is recommended along with a rail car scale.
- The yard will have ample provision for parking, weighing, and unloading trucks. This will include facilities for delivery coordination and ticketing. This facility will also coordinate rail car unloading.

Truck

- When trucks arrive, the drivers will charge a substantial penalty if they cannot offload within 4 hours of arrival. The charge will be relatively large per ton of sawdust. It will not be economically desirable to delay truck unloading due to a surplus in delivery. Therefore:
    - Trucks will be unloaded via a truck tilting device. Two or three such devices will be needed. This will permit the use of flat-bottom trucks.
    - Provision for dumping hopper bottom trucks should also be made. Trucks can be open or closed top.
    - Most truck delivery will take place during daylight hours.

Rail

- We will use rail cars that have bottom discharge gates, and drop the material onto a drag link conveyor that will carry and meter it to a takeaway conveyor.
- Rail car unloading can take place over 24 hours.
- Sawdust rail car shuffling and unloading take place without disturbing other rail deliveries and shipments
- Rail cars will generally arrive in deliveries of not less than 10 cars and not more than 100 cars. This is because of the economies of locomotive usage.

4.8.3 *Comments, Considerations and Reservations*

Rail car overturning equipment is too large and expensive for this use. Pneumatic withdrawal and transfer will require high amounts of energy, and will necessitate expensive equipment such as unloading booms, large blowers, and dust filters, and will release volatiles from the sawdust. Therefore, it would be most efficient if material could be loaded directly from the receiving area into the process.

It would be desirable to perform some sort of blending operation on the incoming stock, to improve consistency. This will improve utilization of additives, without requiring the testing of every incoming load.

Pulp and paper manufacturers move this type of material with belt conveyors. We understand 15 degrees is considered the normal angle of elevation. This means about 3.75ft. of horizontal run is required for every foot of height to be gained. If 20 degrees is considered (as a maximum), then the value is 2.75ft.
Pulp and paper industry does not use bucket elevators for lifting wood stock because the material tends to build up on the buckets.

There are likely to be variations in delivery within a day, a week, the season, etc. Seasonal and weather related variations will need to be accommodated to a certain extent. Delivery may not be consistent with plant usage, within a day, regardless of the attempts to schedule a regular material flow into the plant. It may not be a good idea to take material as delivered right into the process. There could be several reasons for this including a variation in composition, moisture content, and/or yield content. The rates of transfer may not match. (This would require placing a surge hopper at the start of the process and/or make frequent diversions to the process or to the storage pile.

4.9 Special Storage Requirements

4.9.1 *Summary*

A conveyor will carry the raw material over to a storage pile that is formed by a slewing crane conveyor. Material will be taken off the pile by a mechanized reclaimer.

This pile will not be covered by any roof or structure.

The pile will be about 300ft. outside diameter, and about 40ft high for an 8-10 day supply. Because of the widely divergent supply and utilization rates, we recommend this method of bulk pile loading and unloading, and this amount of storage. The ethanol product must be stored using appropriate electrical classification and spill containment consistent with its flammable nature. Similar precautions apply to gasoline storage.

Ammonia must be stored in coded pressure vessels (225 psig design) and must be protected from accidental impact by vehicles or other objects that could rupture them or the ammonia piping.

It is preferred to have a separate diked area for the Sulfuric acid storage tank. In the unlikely event of a serious leak or rupture, no other storage vessels should be affected.

4.9.2 *Assumptions*

- A 4 day supply must be on hand at all times to cover periods of low or no delivery, such as during bad weather.
- It is beneficial to be able to accept large shipments as they arrive, trainloads from other states, etc. (A reasonably sized stacker/unloader system would be able to store about 8-10 days' supply)
- Large amounts of sawdust coming in unit train loads on an infrequent basis, could be stored in the cars themselves.
- A drum magnet will remove ferrous material from the stream just prior to delivery to the process.
- The sawdust is sifted just before it enters the process.

4.9.3 *Comments, Considerations, and Reservations*

At 2,000 tons per day and 45 lb. per cubic foot, an 8-yard loader will need to dump one load every 3.5 minutes on a 24-hour-per-day basis. This would amount to constant usage of this equipment.

Pit reclaimers are less expensive than surface reclaimers, but they require relatively large and deep underground workings. A bulldozer or similar equipment is required for pit reclamation. Water table is an important consideration; a high water table rules out pit reclamation.

Surface reclaimers are easier to repair and the only underground part is the takeaway conveyor. Sawdust can form a vertical wall on takeaway, which also must be considered from a safety standpoint (collapsing wall could bury dozer and operator); reclaimer systems are safe. This is one example where a higher capital expense might be justified by a lower operating expense and reduced downtime.

There will be a provision to divert the material directly to the process, but it is assumed that most of the material will go to the storage pile. Incoming flow could be split with the addition of a conveyor scale and a flow divider valve. The accuracy would not be good, but would probably be adequate for the process. In either case, the flow to the process will either come from the storage pile or incoming stock, but will not come from both at the same time.

4.10 Sawmill Location Maps

4.10.1 *Summary*

The proximity of the source of raw materials to the Ethanol plant site significantly affects the economics associated with this plant. This section displays the major concentration of sawmills for the tri-state region, as can be seen on the accompanying maps (Figs. 4-18 through 4-21).

The largest generators of sawdust in Ohio are located along a North - South corridor in the southeastern portion of the state where the percentage of timberland is the greatest.

In Kentucky, the greatest producers are located along an East - West corridor in the southern part of the state and along a North - South band in the eastern part of the state.

In West Virginia, the largest producers are clustered in the central part of the state.

4.11 Initial Screening of Available Sites

4.11.1 Task Description

As part of the screening study for the BTE facility, available 50 acre sites within the geographical study region were identified for a 2,000 tpd sawdust to ethanol conversion/manufacturing plant. Information requests (see Appendix B) were sent to more than 75 economic development councils, real estate agencies and chambers of commerce within a 56 county area in the tri-state (see Appendix C). This included the South Point Ethanol facility and represented the most concentrated areas of hardwood sawmills. Responses to the information requests were initially screened to ensure the prospective sites met the minimum facility requirements identified (see Appendix B, page 2).

4.11.2 Initial Screening Results

Upon review of more than 40 written correspondences and documented telephone conversations, 33 sites, encompassing 18 counties in Ohio, Kentucky and West Virginia, were identified as meeting minimum facility requirements based on a preliminary analysis (see Appendix D). Further investigation revealed that twenty two of these sites met requirements and these were scheduled for surveys. The purpose of these surveys was to verify site location and logistics, contact local development councils to identify potential business interests and investment incentives, and to examine the local area for compatibility with a sawdust-to-ethanol manufacturing facility. As Appendix E illustrates, the potential sites examined ranged from rural, undeveloped farmland to commercially developed industrial parks with extensive infrastructure. Property costs were often listed as "negotiable", but were baselined to an estimated cost for a fully developed (sewer, water, electrical) site plot to enable fair value comparisons during the final ranking. As discussed in more detail in the financial pro forma analysis (Section 6.0), negotiated tax incentives for a particular site will most likely play a critical role in determining economic viability for any potential site. Those negotiations need to be made at the time/place that a decision to construct is being made.

Based on the site surveys, eleven of the 22 sites visited had partially or fully developed infrastructures which enabled them to meet minimum facility requirements (see Appendix E). Data collected on the sites' transportation costs, raw material availability and ability to meet minimum facility requirements (as detailed in Appendix B) were reviewed. With completion of the site visits, the community issues and local or state environmental requirements were added to the evaluation process as the next section details.

Figure 4-22: Centroid of Tristate Sawmills

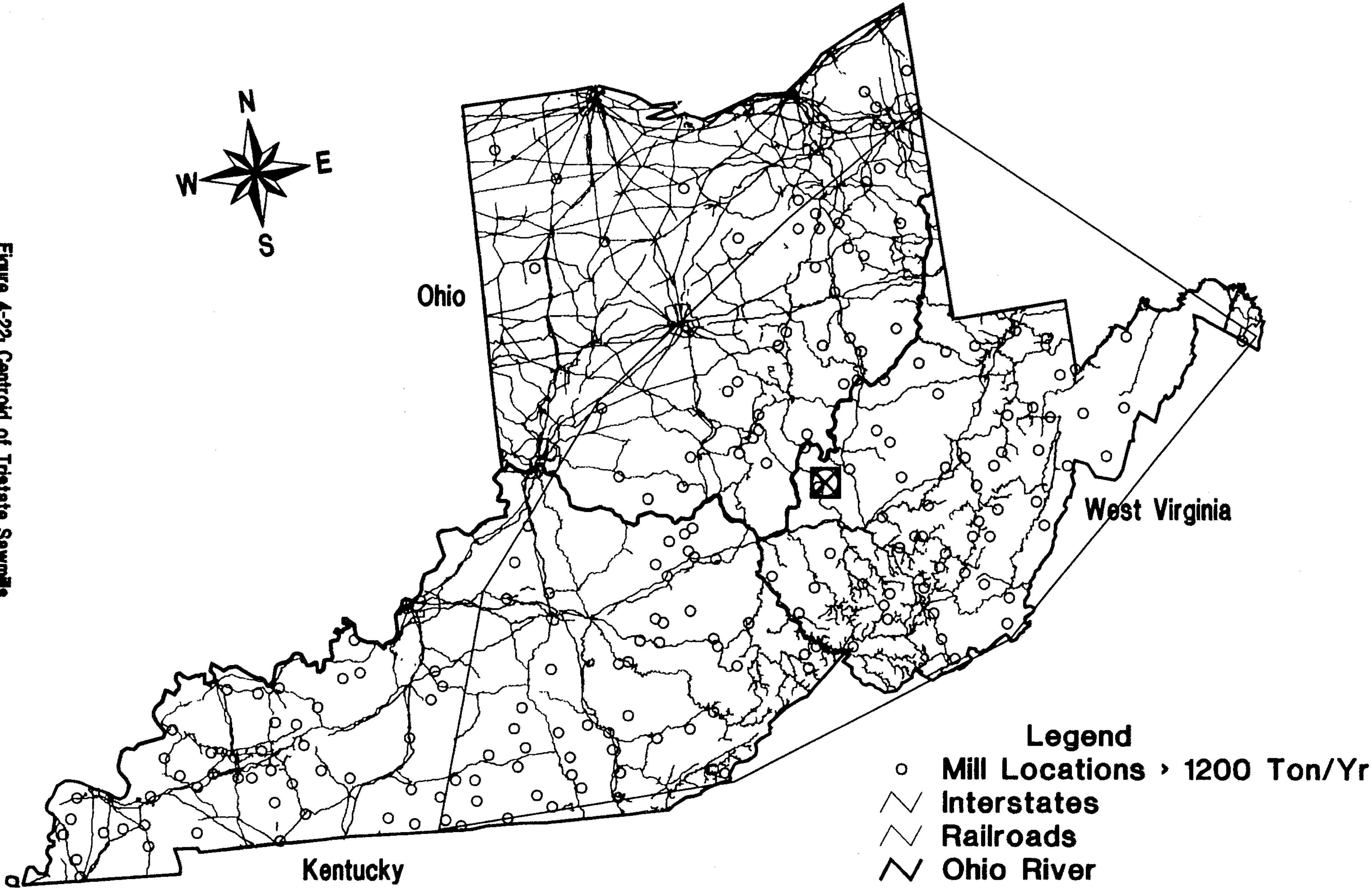


Figure 4-22: Centroid of Tristate Sawmills

Figure 4-23: Sawmills located within 100 mile radius of screened/surveyed locations

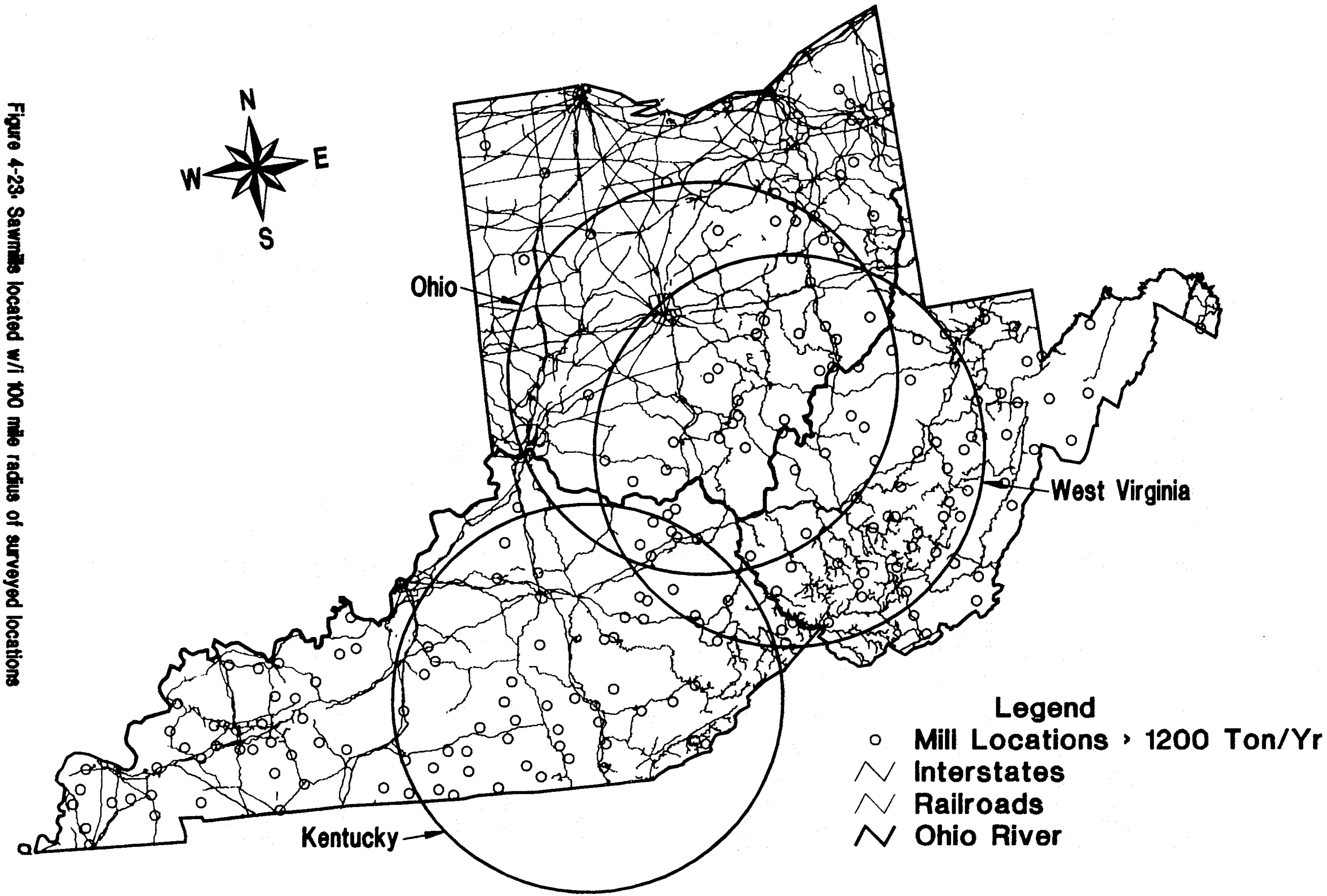


Figure 4-23: Sawmills located w/i 100 mile radius of surveyed locations

4.12.2 *Evaluation of Site Specific Issues*

Required Environmental Permits

As detailed in the environmental discussion in Section 4.5, a 2,000 ton sawdust/day (87,400 gal ethanol/day) BTE facility will be considered a major source of ethanol air emissions. The 1990 Clean Air Act Amendments (CAAA) have resulted in the development of state Title V permitting programs which require:

- Air permits to install (PTI) and permits to operate (PTO) in Ohio
- Air permits to construct (PTC) and operate (PTO) in Kentucky
- Air permits for construction (PFC) and to operate (PTO) in West Virginia

The fee schedule for a construction permit is based on the quantity of emissions and the (ambient air quality) attainment status of the area in which the site is located. Each of the eleven sites that were screened in Section 4.11.2 are situated in counties that are attainment for all of the national ambient air quality standards (NAAQS). Operating permits will be issued for the facility based on the number and type of sources. The actual operating permits are typically issued after construction is completed and the site is surveyed by the agency (to verify compliance with the construction permit). The actual permit fees paid are dependent upon the number of operating permits issued and the actual emissions from the site. The fee schedules for each of the states are similar enough that there is not a significant financial advantage in filing in one state versus another. Typical construction permit fees range from \$2,000-\$5,000 for a facility with potential emissions of 1,000 tons or more. Annual operating fees are approximately \$25/ton, which would result in environmental costs of nearly \$40,000/yr for the potential air emissions estimated in Section 4.5 (~1,300 tons total air pollutants).

Administration of the State Implementation Plans (SIP's) and environmental permits are conducted at the regional or district levels. In West Virginia, the sites that were surveyed were in District V (Mason and Putnam Counties) and District VI (Jackson County), which are managed by the WV Department of Environmental Protection offices in St. Albans and Parkersburg respectively. In Ohio, the Southeast District Office in Logan, Ohio administers the air programs for Ross and Hocking Counties . Wayne, Pulaski and Laurel counties in Kentucky are administered from offices in London, Kentucky.

A notable distinction does exist in the individual states' policy towards "air toxics", which are pollutants that have significance levels or limits (these are in addition to, or in conjunction with, the 189 hazardous air pollutants identified in Section 112 of the CAAA). The Kentucky Department of Environmental Protection (KYDEP) has established significance levels for more than 600 listed air toxic pollutants (401 KAR 63:022, Appendix B). Though fugitive BTEX, sulfuric acid and possible ammonia emissions are the only air toxics identified, this could impact on the type and level of air pollution control, as well as permit preparation/approval time. In contrast, West Virginia has listed 19 regulated air toxics with potential emissions levels, of which only fugitive benzene emissions could be a concern for the BTE facility. In general, Ohio and West Virginia do not have such a definitive air toxics policy.

The Wastewater Treatment (WWT) system in the BTE facility is designed to ensure that treated effluent can be discharged to the surface waters of the state (or federal waterways). A National Pollutant Discharge Elimination System (NPDES) permit will need to be acquired from ORSANCO and a construction permit will need to be obtained from the Corps of Engineers if direct discharge to the Ohio River (80% of sites surveyed) is involved. If wastewater discharge to the sanitary sewer is required, permits from the local MSD would need to be secured, which, in the case of those sites without a developed sewage system, could be a significant deterrent to site selection. These fees vary considerably, depending on the type and level of contamination in the wastewater, but an average value of $1.50/1,000 gal is predicted.

Solid waste disposal of the boiler ash and/or unprocessed lignin does not require a permit. Local fees for solid waste disposal should be negotiated with different landfills at the time of site selection, and the cost of disposal is not an issue that warrants distinction from state to state.

To assess the relative difficulty in securing of permits, each site has been assigned a numerical value (0=difficult or unusually costly, with potential operating restrictions; 1=average cost and ease of permitting, with no anticipated operating restrictions; 2=less than average cost or permitting effort, with precedence for permitting the facility or adjacent property) corresponding to the ease, likelihood and relative cost to secure the necessary environmental permits. All the sites were assigned either a 1 or 2 during final ranking, based on the site surveys and review of environmental requirements.

Archaeological Considerations

Many of the sites were located in the Ohio River Valley, which is an area rich in American Indian history and archaeology. As a result, some of the properties are located in areas that require historical society/archaeological evaluation before permission is granted for construction or operation. Though not assessed separately, this is a permitting issue, and was taken into consideration during the environmental permitting evaluation previously described.

Geotechnical Evaluations

Some of the sites had Phase I Environmental assessments already conducted, with geotechnical borings analyzed to confirm the absence of environmental pollution and to determine the site geology for construction purposes. Since many of the sites were virgin farmland with no previous industrial or commercial history, these sites were assumed to be environmentally clean and geotechnically suitable for construction. Those sites with good assessment data fared best in the final ranking, as some architectural or geotechnical evaluation could be made (0=minimally acceptable, requires further investigation to document acceptability; 1=acceptable, some environmental/geotechnical data collected, with no reason to suspect potential hazards; 2=excellent; no historical environmental/geotechnical problems with detailed assessments to confirm).

Known Site Competing Uses

If any of the sites were known to be under consideration by other potential buyers for manufacturing construction or commercial use, those observations were noted in the project files. However, none of the eleven sites were noted to be under <u>serious</u> consideration (bid in progress, follow-up visits or requests for additional information, etc.) at the time of the site surveys by any other potential buyers or tenants. Hence, this category of information did not enter into the final ranking. However, it is an evaluation that needs to be revisited at the time of negotiating the purchase price, and considered if the situation changes.

Site Zoning Restrictions

None of the eleven sites initially screened and surveyed were subject to zoning restrictions. Three sites in Pulaski County, KY that were surveyed were zoned Industrial (Lake Cumberland Regional Industrial Park and Valley Oak Commerce Complex). Another site in Laurel County located on KY State Route (SR) 80 was also part of an industrial park. All other properties visited in KY were farmland and were located on state route 90.

There were no zoning requirements for any of the sites in West Virginia. All the sites in Mason County were farmland just off of, or situated directly on, SR 62 or SR 2 and the Ohio River. There were nearby industrial complexes along SR 62 intermingled with saleable farmland. One property, the Jackson County Maritime and Industrial Park site near Millwood WV, is a fully developed industrial tract.

Of eleven sites visited in Ohio, one of the three initially screened as acceptable was listed as an industrial site (Hocking County, Industrial Site #3). The other two sites in Ross County (Kempton site, Mead site) were farmland or partially developed (warehouse, tree nurseries) agricultural properties. None had zoning restrictions.

As zoning does not appear to be an issue for any of the screened sites, there was no relative numerical value identified in the final ranking.

Residential Density Near the Sites

None of the eleven sites were located in densely populated areas. All appeared to be in areas where a qualified workforce was available (vocational or technical training). In line with the location of sensitive nearby receptors, a numerical listing was made to aid in the final selection of a potential greenfield location [0=school, residential area or sensitive receptor located within 1/2 mile; 1= no school or residential areas within 1 miles; 2= no school or sensitive receptor within 2 miles].

Industrial Designated Waterways

Two industrial waterways, the Ohio River and Kanawaha River (South Buffalo site) are immediately adjacent to the sites in West Virginia, providing ready access for barge shipments of ethanol and/or receipts of sawdust (if marshaling yards are established).

The potential "greenfield sites" surveyed in Ohio are not located on the Ohio River, but are within a short distance (< 35 miles), and easily accessed through local state routes.

None of the sites surveyed in Kentucky are located on major industrial waterways, and the nearest inland route that can accommodate barges is the Cumberland River out of Burnside (Pulaski County) Kentucky. However, this waterway is less than 9 feet deep and not practical for any intended barge traffic.

If a site has the potential for accessing major industrial waterways, this was reflected in the assessment of the site's "quality of transportation".

Project Development Time (Permitting, Ownership)

In discussion with members of the economic development councils during the surveys in each of the three states, a 2-3 month period of time appeared to be the average duration for securing the required environmental and construction permits. Public notification was included in that time period, and one site

(Jackson County Maritime and Industrial Park) noted that previous tenants had secured the necessary paperwork and approvals within 45 days.

Undeveloped sites without environmental assessments, geotechnical or architectural surveys, and in need of utility infrastructure, obviously involve more project development time than those developed sites or industrial parks. As this was not considered a critical factor relative to any of the eleven sites, a value of zero was assigned to any completely rural, undeveloped site, and a value of one was given to acknowledge the less time consuming task of executing the project for a developed site or industrial park.

Natural Resources (Wetlands, Wildlife) Issues

Only one of the sites visited appeared to have any wetland areas on or adjacent to the site. There was enough land available at the South Buffalo West Virginia site to exclude the wetlands area from the 50 acres needed for the sawdust-to-ethanol facility. However, if this site was considered a preferred location, an environmental assessment would need to be performed to confirm that ethanol emissions and related organics do not have a detrimental affect on the area.

Availability and Quality of Existing Roads, Rail Lines and Barge Lines

As detailed in the previous discussion of the industrial waterways, barge transportation routes in Ohio and West Virginia are well established along the Kanawaha and Ohio Rivers.

All of the sites surveyed are within 50 miles of an Interstate. The sites in southeast Ohio are the furthest (30-50 miles) from interstate transportation routes (I-77 to the east; I-70 to the north), but four major U.S. highways (Routes 23, 33, 35, and 50) and a four lane divided highway (SR-32) provide adequate thoroughfares for truck transportation.

All of the sites in West Virginia are located along state routes 2 and 62, near U.S. Routes 33 and 35, and all within 20 miles of I-77 or I-65.

Of the sites screened in Kentucky, all are within 35 miles of I-75, and two are located on or just off of SR 80, which is a four lane divided highway across the state. The other site is located on route 90, which is a two lane highway approximately 15 miles from SR-80 or U.S. 27.

CSX rail lines run along SR-2 and 62 in West Virginia and are adjacent or located on 4 out of 5 of the properties screened (Mason and Jackson counties). Rail spurs can easily be installed at reasonable costs in these locations. One of the properties (Jackson County Maritime & Industrial Park) has already discussed/negotiated rail spur installations with the railroad on behalf of its tenants, and CSX is amenable to the installation. The fifth property in South Buffalo, WV (Putnam County) has Conrail lines across the property.

Two of the three sites in Ohio have the potential for rail spur installations, with one only requiring an upgrade of an existing spur (Mead site, Ross County). In Kentucky, only the Lake Cumberland Industrial Park site in Pulaski had rail and the potential for spur installation with Norfolk-Southern railroad. The Somerset-Pulaski County Development Foundation has already proposed a rail off-loading facility, and the rail facility, in combination with U.S. Highway 27 bypass construction/connection with SR 80 (1997), will provide integrated rail and highway transportation.

Each of the sites has at least acceptable (grade 0), if not excellent (grade 4) highway access to interstates and the surrounding hardwood sawdust suppliers. Truck transportation will be the primary means of transportation for the sawdust unless marshaling yards are established, and since transportation is one of the three most important criteria for selection of a plant site ("Preliminary Chemical Engineering Plant Design", Baasel, William D.), the transportation factor (including potential for barge and possibility of rail) has been weighted more heavily than other factors. Those sites with fully developed highway, rail and/or barge facilities compared favorably to those sites relying on two lane highways without rail or barge.

Site Distance to Saw Dust Suppliers

There are more than 180 large sawmills (>1200 tons/year) in Kentucky, Ohio and West Virginia. The statistical center of mass or centroid for these large sawmills is depicted in Figure 4-22. A review of their locations and the smaller sawmills indicates that approximately 50% of the sawmills within the tri-state are within 100 miles of the sites in West Virginia, approximately 40% of the sawmills are within 100 miles of the sites screened in Kentucky, and an estimated 30% of the sawmills are within a 100 mile radius of the sites prescreened in Ohio (Figure 4-23). As part of a comprehensive final ranking, proximity to raw material suppliers is one of the three most important factors in selecting a chemical engineering plant site. As a result, even though the relative distances or percentages were close enough that transportation cost differentials are probably not significant, an attempt was made to assign some relative value to those sites closest to the centroid of the saw mill "mass".

Sensitive Nearby Receptors (Schools, Churches, Parks)

As described in the section on population density, none of the sites are located in densely populated areas. A few are located adjacent (within 1/4 mile from projected site boundary) to residential areas, and in those cases, this is reflected in a simple evaluation of adjoining land usage, residential density and sensitive receptors during the final ranking.

4.13 Final Ranking

4.13.1 *Task Description*

As part of the final ranking, after being physically surveyed, the sites were evaluated according to economic, environmental, and community considerations, in addition to good engineering siting practices [as defined in "Preliminary Chemical Engineering Plant Design 'Site Selection'", Chapter 2, 2nd ed., Baasel, William D.]. The previous discussion detailed the environmental and community considerations, as well as the methodology proposed for quantifying the relative site specific issues so a single site could be selected. The following discussion qualitatively assesses some of the economic factors and details how the sites met other minimum facility requirements or engineering siting considerations, combining both these assessments to select a specific greenfield site for further economic feasibility studies.

4.13.2 *Economic and Engineering Siting Considerations*

Appendix G ranks the eleven sites that were initially screened from the twenty two sites surveyed in the tri-state area. Belcan Engineering Group has prepared this evaluation to identify a site for the purposes of detailing the capital costs, operating costs, and economic viability of the sawdust to ethanol process at a "greenfield" location. A more detailed assessment of technical (geotechnical, architectural, civil, etc.) and financial (negotiated tax incentives, various financing alternatives, etc.) issues, should be conducted before any site is selected for purchase and construction. As evidenced in the previous discussion, many of the sites were without technical information that could be compared to those sites with environmental or geotechnical assessments, and much of the financial detail should be evaluated/negotiated at the time of purchase.

4.13.3 *Economic Considerations*

Economic factors involved in selecting a site can be discussed in terms of capital investment costs [land costs, equipment, infrastructure development (utilities, access roads, etc.), site preparation] fixed operating costs (taxes, insurance) and operating costs (raw materials, utility costs, etc.). All can vary site to site, but because capital investment costs and fixed operating costs rely heavily on negotiated financing plans and tax incentives established at the time of purchase, these factors are assumed comparable state to state. Conversations with economic development council members have indicated that federal economic development association (EDA) grants and tax incentives were available in each area for a business willing to locate and employ people in their county or area. Therefore, the remaining discussion will focus on operating costs (raw material costs, transportation costs, etc.) that can be evaluated in selecting a site.

In preliminary cost estimates, the cost of "green" sawdust was estimated at an average of $12/ton, assuming competitive market forces for sawdust drives the price higher than current average values ($5-$10/ton). Regardless of the assumed price, transportation of the sawdust to the proposed BTE facility would constitute a significant part of the raw material cost. As much as 15% of the sawdust currently available is unclaimed, and as such, is "given" away, which involves the generator paying to have the waste hauled away. Transportation costs can represent as much as 70% of the cost/profit loss for the rest of the sawdust sold for fuel, animal bedding and charcoal wood.

In line with the discussion of transportation costs, site distance to the saw dust suppliers plays an important part in determining how much of the estimated $7.9MM/yr will actually be spent on acquiring and transporting sawdust from the mills. As described earlier and detailed in Appendix G, the sites surveyed in West Virginia were ranked high, with Kentucky sites next, followed by Ohio. This reflects the closer proximity of the sawmills (50% within 100 mile radius) to the sites surveyed in Kentucky and Ohio.

4.13.4 *Engineering Siting Considerations*

Many of the engineering siting considerations were identified in the minimum facility requirements that were transmitted (and subsequently confirmed during the site surveys) in the information requests sent to the respective real estate agencies, chambers of commerce and economic development councils. These have been ranked in Appendix G as previously discussed, but some details are worth noting here.

Availability of utilities was noted in Appendix G, but not comparatively evaluated, since many of the sites would have their infrastructure developed further (by county or regional economic development organizations) if a potential employer were to locate in the area. Sites above prolific aquifers (groundwater supply) were favorably noted versus those sites with city water or questionable water supply, but no quantitative determination was made. Likewise, sites with sizable effluent receptor streams were positively evaluated, though no quantitative value was assigned.

Cost of land was noted where prices were available, and ranges of $6,000-$70,000 per acre were noted during the surveys. Most prices, especially for those properties owned/leased by the county/economic councils, were listed as negotiable.

4.13.5 *The Greenfield Selection*

As the combined total in Appendix G indicates, and the previous qualitative discussions support, the Jackson County Maritime & Industrial Park near Millwood, WV has been selected as the greenfield site. Estimated capital and operating costs for development of this site have been incorporated into the greenfield cost estimate. As Figure 4-24 depicts, the selected site is very near the center or centroid of the largest primary sawdust suppliers.

Figure 4-24: Proximity of selected greenfield site to centroid of tristate sawmills

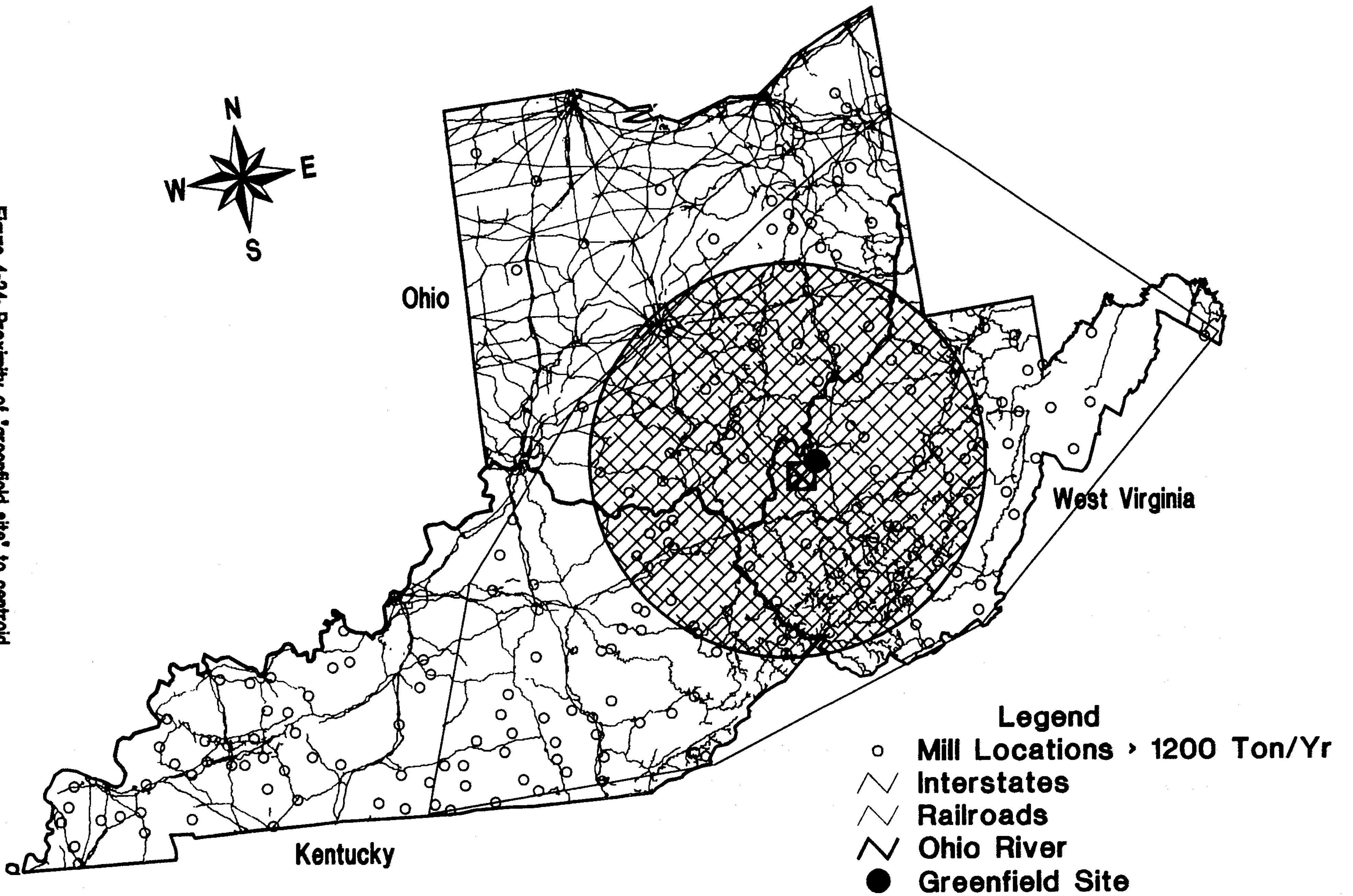


Figure 4-24: Proximity of "greenfield site" to centroid

5.0 Budgetary Capital & Operating Costs

A primary part of the sawmill waste Biomass-To-Ethanol (BTE) screening study involved identifying the capital and operating costs for a facility processing 2,000 tons per day of sawdust to ethanol. A technical evaluation of the BTE process described in the Solar Energy Research Institute (SERI) report entitled "Technical and Economic Analysis of an Enzymatic Hydrolysis Based Ethanol Plant" (June 1991) was used as a starting point for this screening study. As the original process involved fermentation of hardwood chips (versus sawdust), key changes or assumptions for equipment selection and cost estimation included:

- Neutralization with ammonia instead of lime
- Addition of an ethanol dehydration process and associated equipment with operation at elevated pressure for efficient thermal distillation
- Changes in size, design pressure or mixing configuration for selected fermentation vessels based on good engineering practice and economic considerations
- Utilization of existing boilers at the SPE facility, versus high pressure boiler/turbogenerator installation

Based on these changes and consistent with the process flow diagrams (Figures 4-4 thru 4-16) described in Section 4.3, the equipment list in Appendix H was compiled. From this listing, the bare plant capital (1995 dollars) cost for equipment and construction of the BTE facility at the "greenfield" Millwood, WV location was estimated to be $110MM (Table 5-1). Since startup costs and working capital are also part of major capital construction projects, the total capital investment for the installation is $120.36MM (Table 5-2, page 1).

Total operating costs (1995 dollars) for the greenfield facility (fixed plus variable costs) are estimated at $21MM/yr (Table 5-2, page 2). These annual operating costs are reduced with a saleable $5MM/yr worth of surplus electricity that is generated from the boiler/turbogenerator. Sales of recovered CO2 provide $330,000 in additional revenue which also reduces net cost of production. These adjustments to the operating costs, including the cost to landfill the solid waste (boiler ash) from the facility, reduce the annual net cost of production to $15.6MM from $20.6MM. This net cost of production (Table 5-2, page 2) is combined with the $18.7MM in capital charges (amassed from interest/debt on the equipment and capitalized labor) to calculate an annual denatured fuel cost of $34.24MM. Additional cost estimate details for the site are provided in Appendix I.

As summarized, Tables 5-3 and 5-4 reveal the comparable capital and operating costs for installation of the BTE process at the existing SPE facility. Bare plant capital costs are estimated at $81MM/yr and operating costs are $20MM/yr. No credit for electricity sales is realized since the existing SPE boiler system is utilized (versus new boiler/turbogenerator), but a $1.5MM waste fuel sales credit results from burning lignin (versus coal). The primary difference in cost for installation at SPE is the reduction in capital investment associated with the high pressure boiler and turbogenerator. However, the net cost of production (net of byproduct credit) is substantially higher, offsetting most of this capital cost savings. Appendix J contains the cost estimate details for the SPE facility.

Tables 5-2 and 5-4 utilize a 15.5% factor for annual capital charges. Such a factor is commonly used in preliminary economics. Based on the highly leveraged financing assumed in the Pro Forma analysis (Section 6.0), a 14% capital charge would result in denatured fuel costs similar to those identified in the more detailed Pro Forma assessment.

For the purposes of installing an engineering demonstration unit for testing and continued technical evaluation, a cost estimate identifying a capital cost investment requirement of $10.3MM is included in Table 5-5. In addition, approximately $1MM may be needed to operate this facility.

5.1 Key Assumptions

Equipment Basis for Cost Estimate

The equipment selection and sizing for developing the budgetary cost estimate for the screening study is based on processing 2,000 green tons per day of hardwood sawdust to produce about 87,400 gallons per day (100% ethanol basis) of 199° proof ethanol. Byproduct lignin is utilized as fuel to produce high pressure steam for power generation. Steam extraction from the power turbine is used to provided process heat. Exported power, after meeting plant needs, is estimated at 15.4 MW. The basic process design is similar to the design used in the SERI report of June 1991 (SERI/TP-232-4295) for producing ethanol from hardwood chips. Some variations from that design , in addition to size, were incorporated where it was thought to be appropriate. These variations are discussed briefly as follows:

- Though concerns for use of carbon steel were identified in preliminary review, the high costs of utilizing stainless steel requires that the material of construction be carbon steel rather than 304SS for an economically viable plant. Initially it was felt that stainless steel should be used for continuous fermentations in order to minimize surface pitting that could harbor bacterial contamination that would be difficult to remove. Corrosion rates are consistent with the use of carbon steel. It may be prudent to identify other measures for controlling infections, and it is acknowledged that antibiotics will be required periodically .

- Several large fermenters and other tanks were reduced in design pressure from 50 psig to atmospheric in order to minimize wall thickness and cost. In most cases the higher design pressure had been used to provide for compressed air transfer of the tank contents. It is felt that properly designed pumping systems can be used for transfers with a net capital cost savings. Obviously, the economic choice between compressed air transfer and pumping will be affected by the construction materials used.

- Side entering agitators were used where feasible to avoid the high cost of long agitator shafts.

- One extra xylose fermenter and two extra SSF fermenters were included to allow for a rotating cycle of emptying and cleaning successive fermentation vessels without requiring shutdown or loss of throughput. This is considered necessary in order to be able to control potential infections.

- Front end material handling was changed to be suitable for sawdust as opposed to chips.

- Ammonia is used for hydrolysate neutralization instead of lime. Our preliminary material balance indicates that ammonia levels will remain below toxic levels. This change eliminates the severe gypsum fouling that would occur with lime addition.

- Equipment for product ethanol dehydration is included.

- The volume of the inoculum seed fermenters was reduced based on the premise that continuous fermentations do not usually require a continuous supply of inoculum. However, this may be a problem due to inhibitors that may be generated during prehydrolysis. This should be tested prior to commercializaton.

TABLE 5-1: GREENFIELD SITE CAPITAL COST

TITLE: SCREENING STUDY FOR SAWMILL WASTE
CLIENT: NATIONAL RENEWABLE ENERGY LABORATORY
LOCATION: MILLWOOD, WV

DATE: 29-Aug-95
COST ENG: J.SLOMBA

	SCOPE DESCRIPTION	LBR HRS	LABOR $	FLD MTL $	MJR PUR $	SUBCONTRACT $	TOTAL $
1	DEMOLITION / EXPENSE PROCESS AREAS	0	0	0	0	250,000	250,000
2	EQUIPMENT						
	100- WOOD HANDLING	2,000	80,000	11,200	701,000	0	792,200
	200-PREHYDROLYSIS	4,842	193,700	13,900	6,666,600	0	6,874,200
	300-XYLOSE FERMENTATION	746	29,900	5,000	322,800	1,185,000	1,542,700
	400-CELLULASE PRODUCTION	778	31,200	6,600	448,500	375,000	861,300
	500-SSF	2,369	94,700	24,100	1,232,600	3,177,000	4,528,400
	600-ETHANOL RECOVERY	2,112	84,500	8,300	1,261,600	100,000	1,454,400
	600-DEHYDRATION	1,680	67,200	11,200	790,200	0	868,600
	700-OFF-SITE TANKAGE	675	27,000	3,200	252,500	545,000	827,700
	800-WASTE TREATMENT	1,050	42,000	6,200	422,600	625,000	1,095,800
	900-UTILITIES	11,467	458,700	121,400	8,542,700	15,880,000	25,002,800
3	EQUIP. FOUNDATIONS, & SUPPORTS	30,100	1,204,000	861,000	0	0	2,065,000
4	PIPING	114,400	4,576,000	5,448,000	0	3,070,000	13,094,000
5	INSTRUMENTATION	43,600	1,744,000	4,358,000	0	0	6,102,000
6	ELECTRICAL	55,200	2,208,000	1,841,000	0	0	4,049,000
7	BUILDINGS	18,800	750,000	1,350,000	150,000	750,000	3,000,000
8	YARD, SITEWORK, & UNDERGROUND	32,100	1,284,000	1,607,000	0	500,000	3,391,000
9	OTHER	16,100	644,000	3,214,000	0	0	3,858,000
10	LAND	0	0	750,000	0	0	750,000
	OTHER ALLOWANCES						
	TOTAL DIRECT COST	338,019	13,518,900	19,640,100	20,791,100	26,457,000	80,407,100
	SALES TAX						0
	PREMIUM TIME						473,200
	CONSTRUCTION COST TOTAL						80,880,300
	ENGINEERING / DESIGN						12,132,000
	CONSTRUCTION MANAGEMENT						3,235,200
	AUTOMATION DESIGN						1,617,600
	CLIENT ENGINEERING						2,507,300
	SUBTOTAL						100,372,400
	CONTINGENCY						9,635,800
	rounding						(8,200)
	TOTAL ESTIMATED COST						110,000,000

Table 5-1: Greenfield Site Capital Cost

TITLE : SCREENING STUDY FOR SAWMILL WASTE
CLIENT: NATIONAL RENEWABLE ENERGY LABORATORY
LOCATION: MILLWOOD, WEST VIRGINIA

EQUIPMENT COST			MILLION $
100 WOOD HANDLING			0.70
200 PREHYDROLYSIS			6.67
300 XYLOSE FERMENTATION			1.51
400 CELLULASE PRODUCTION			0.82
500 SSF			4.41
600 ETHANOL RECOVERY			1.36
600 DEHYDRATION			0.79
700 OFF-SITE TANKAGE			0.80
800 WASTE TREATMENT			1.05
900 UTILITIES			9.12
TOTAL EQUIPMENT			27.23
OTHER FACILITY COMPONENTS			
LAND			0.75
DEMOLITION/SITE CLEARANCE			0.25
EQUIPMENT ERECTION			1.32
EQUIP. FOUNDATIONS & SUPPORTS			2.06
PIPING			13.09
INSTRUMENTS			6.10
ELECTRICAL			4.05
BUILDINGS			3.00
YARD SITEWORK & UNDERGROUND			3.39
BOILER PKG			15.3
MISCELLANEOUS			3.86
PREMIUM TIME			0.47
ENGINEERING			12.13
CONSTRUCTION MANAGEMENT			3.24
OTHER COST			4.13
CONTINGENCY			9.63
TOTAL FIXED CAPITAL -			110.00
STARTUP COSTS	110.00	5%	5.50
WORKING CAPITAL	4.86 <----	<-------	4.86
TOTAL CAPITAL INVESTMENT			120.36

Table 5-2: Cost Summary for Greenfield Site

TOTAL CAPITAL INVESTMENT $120.35 MM

CAPITAL INVESTMENT/ANNUAL GALLON $3.90 ESCALATION since 1990 @ 10%

	BASE USAGE		RATE PER TON	CENTS PER LB	MM$/YR	CENTS/GAL
MATERIALS						
WOOD	666,667	T/YR	$10	0.50	6.67	21.59
ACID	5,369	T/YR		4.13	0.44	1.43
LIME	-	T/YR		2.48	-	-
AMMONIA	2,541	T/YR		5.50	0.28	0.91
CORN STEEP LIQUOR	293	T/YR		12.10	0.07	0.23
NUTRIENTS	84	T/YR		13.64	0.02	0.07
ANTIFOAM	17	T/YR		28.60	0.01	0.03
GLUCOSE	258	T/YR		58.30	0.30	0.97
GASOLINE	1,500,000	GAL/YR	0.75	$/GAL	1.13	3.64
DIESEL - ALLOW	2,500	T/YR		14.09	0.70	2.28
DEWATERING CHEMICALS	100	T/YR		10.00	0.02	0.06
CIP CHEMICALS					0.05	0.16
BOILER CHEMICALS					0.12	0.40
COOLING WATER CHEMICALS					0.48	1.54
MAKEUP WATER	930	GPM			0.04	0.14
S/T VARIABLE OPERATING COST					10.34	33.47
FIXED OPERATING COST						
LABOR	35	EA	$32,800		1.15	3.72
FOREMAN	9	EA	$37,400		0.34	1.09
SUPERVISION	1	EA	$44,000		0.04	0.14
DIRECT OVERHEAD	$1,528,600	LABOR $	45%		0.69	2.23
MAINTENANCE	110.00	FIXED CAPITAL	3%		3.30	10.69
GENERAL PLANT OVERHEAD	$4,828,600	LABOR $ + MAINT $	65%		3.14	10.16
INSURANCE & TAXES	110.00	FIXED CAPITAL	1.5%		1.65	5.34
S/T FIXED OPERATING COST					10.31	33.37
S/T OPERATING COST					20.64	66.84
BY-PRODUCT CREDITS				RATE PER UNIT QTY		
ELECTRICITY - CREDITS	(15.4)	MWe		4.00	(4.93)	(15.96)
CO2 SALES	47,328.0	T/YR		7.00	(0.33)	(1.07)
SOLIDS DISPOSAL (LB) (ASSUME)	25	LB/HR		1.00	0.20	0.65
S/T CREDITS					(5.06)	(16.38)
NET COST OF PRODUCTION					15.58	50.46
ANNUAL CAPITAL CHARGE	120.36		15.5%		18.66	60.41
DENATURED FUEL COST					34.24	**110.88**

TABLE 5-3: EXISTING SITE CAPITAL COST

TITLE: SCREENING STUDY FOR SAWMILL WASTE
CLIENT: NATIONAL RENEWABLE ENERGY LABORATORY
LOCATION: SOUTH POINT, OHIO

DATE: 29-Aug-95
COST ENG: J.SLOMBA

	SCOPE DESCRIPTION	LBR HRS	LABOR $	FLD MTL $	MJR PUR $	SUBCONTRACT $	TOTAL $
1	DEMOLITION / EXPENSE	0	0	0	0	250,000	250,000
	PROCESS AREAS						
2	EQUIPMENT						
	100- WOOD HANDLING	2,000	80,000	11,200	701,000	0	792,200
	200-PREHYDROLYSIS	4,842	193,700	13,900	6,666,600	0	6,874,200
	300-XYLOSE FERMENTATION	746	29,900	5,000	322,800	1,185,000	1,542,700
	400-CELLULASE PRODUCTION	778	31,200	6,600	448,500	375,000	861,300
	500-SSF	2,359	94,300	24,100	1,232,600	3,177,000	4,528,000
	600-ETHANOL RECOVERY	2,462	98,500	10,300	1,383,600	100,000	1,592,400
	600-DEHYDRATION	1,680	67,200	11,200	790,200	0	868,600
	700-OFF-SITE TANKAGE	555	22,200	2,700	228,400	150,000	403,300
	800-WASTE TREATMENT	1,000	40,000	5,200	392,600	625,000	1,062,800
	900-UTILITIES	6,612	264,500	92,600	2,696,100	3,930,000	6,983,200
3	EQUIP. FOUNDATIONS, & SUPPORTS	25,100	1,004,000	716,000	0	0	1,720,000
4	PIPING	117,900	4,716,000	5,615,000	0	1,786,000	12,117,000
5	INSTRUMENTATION	36,300	1,452,000	3,626,000	0	0	5,078,000
6	ELECTRICAL	34,000	1,360,000	1,133,000	0	0	2,493,000
7	BUILDINGS	6,300	250,000	450,000	50,000	250,000	1,000,000
8	YARD, SITEWORK, & UNDERGROUND	28,800	1,152,000	1,440,000	0	0	2,592,000
9	OTHER	11,000	440,000	2,197,000	0	0	2,637,000
10	LAND	0	0	750,000	0	0	750,000
	OTHER ALLOWANCES						
	TOTAL DIRECT COST	282,434	11,295,500	16,109,800	14,912,400	11,828,000	54,145,700
	SALES TAX						0
	PREMIUM TIME						395,300
	CONSTRUCTION COST TOTAL						54,541,000
	ENGINEERING / DESIGN						10,908,200
	CONSTRUCTION MANAGEMENT						2,727,100
	AUTOMATION DESIGN						1,418,100
	CLIENT ENGINEERING						2,454,300
	SUBTOTAL						72,048,700
	CONTINGENCY						9,006,100
	rounding						(54,800)
	TOTAL ESTIMATED COST						81,000,000

Table 5-3: Existing Site Capital Cost

TITLE : SCREENING STUDY FOR SAWMILL WASTE
CLIENT: NATIONAL RENEWABLE ENERGY LABORATORY
LOCATION: SOUTH POINT, OHIO

	EQUIPMENT COST				MILLION $
100	WOOD HANDLING				0.70
200	PREHYDROLYSIS				6.67
300	XYLOSE FERMENTATION				1.51
400	CELLULASE PRODUCTION				0.84
500	SSF				4.41
600	ETHANOL RECOVERY				1.48
600	DEHYDRATION				0.79
700	OFF-SITE TANKAGE				0.38
800	WASTE TREATMENT				1.02
900	UTILITIES				6.63
	TOTAL EQUIPMENT				24.43
	OTHER FACILITY COMPONENTS				
	LAND				0.75
	DEMOLITION/SITE CLEARANCE				0.25
	EQUIPMENT ERECTION				1.10
	EQUIP. FOUNDATIONS & SUPPORTS				1.72
	PIPING				12.12
	INSTRUMENTS				5.08
	ELECTRICAL				2.49
	BUILDINGS				1.00
	YARD SITEWORK & UNDERGROUND				2.59
	BOILER PKG				
	MISCELLANEOUS				2.63
	PREMIUM TIME				0.39
	ENGINEERING				10.90
	CONSTRUCTION MANAGEMENT				2.73
	OTHER COST				3.87
	CONTINGENCY				8.95
	TOTAL FIXED CAPITAL -				81.00
	STARTUP COSTS	81.00		5%	4.05
	WORKING CAPITAL	3.91 <----	<-------		3.91
	TOTAL CAPITAL INVESTMENT				88.96

TOTAL CAPITAL INVESTMENT $88.95 MM

CAPITAL INVESTMENT/ANNUAL GALLON $2.88 ESCALATION since 1990 @ 10%

	BASE USAGE		RATE PER TON	CENTS PER LB	MM$/YR	CENTS/GAL
MATERIALS						
WOOD	666,667	T/YR	$10	0.50	6.67	21.59
ACID	5,369	T/YR		4.13	0.44	1.43
LIME	-	T/YR		2.48	-	-
AMMONIA	2,541	T/YR		5.50	0.28	0.91
CORN STEEP LIQUOR	293	T/YR		12.10	0.07	0.23
NUTRIENTS	84	T/YR		13.64	0.02	0.07
ANTIFOAM	17	T/YR		28.60	0.01	0.03
GLUCOSE	258	T/YR		58.30	0.30	0.97
GASOLINE	1,500,000	GAL/YR	0.75	$/GAL	1.13	3.64
DIESEL - ALLOW	2,500	T/YR		14.09	0.70	2.28
DEWATERING CHEMICALS	100	T/YR		10.00	0.02	0.06
CIP CHEMICALS					0.05	0.16
BOILER CHEMICALS					0.12	0.40
ELECTRIC POWER	6.4	MWe		4.50	2.30	7.46
COOLING WATER CHEMICALS					0.48	1.54
MAKEUP WATER	930	GPM			0.04	0.14
S/T VARIABLE OPERATING COST					12.64	40.93
FIXED OPERATING COST						
LABOR	35	EA	$32,800		1.15	3.72
FOREMAN	9	EA	$37,400		0.34	1.09
SUPERVISION	1	EA	$44,000		0.04	0.14
DIRECT OVERHEAD	$1,528,600	LABOR $	45%		0.69	2.23
MAINTENANCE	81.00	FIXED CAPITAL	3%		2.43	7.87
GENERAL PLANT OVERHEAD	$3,958,600	LABOR $ + MAINT $	35%	USE	1.39	4.49
INSURANCE & TAXES	81.00	FIXED CAPITAL	1.5%		1.22	3.93
S/T FIXED OPERATING COST					7.25	23.47
S/T OPERATING COST					19.89	64.40
				RATE PER UNIT QTY		
BY-PRODUCT CREDITS						
ELECTRICITY - CREDITS	-	MWe		4.00	-	-
CO2 SALES	47,328.0	T/YR		7.00	(0.33)	(1.07)
FUEL CREDITS	(186.0)	MMBTU/HR		1.00	(1.49)	(4.82)
SOLIDS DISPOSAL (LB) (ASSUME)	25	LB/HR		1.00	0.20	0.65
S/T CREDITS					(1.62)	(5.24)
NET COST OF PRODUCTION					18.27	59.16
ANNUAL CAPITAL CHARGE	88.96		15.5%		13.79	44.65
DENATURED FUEL COST					32.06	**103.81**

TABLE 5-5: EDU CAPITAL COST SUMMARY

TITLE: SCREENING STUDY FOR SAWMILL WASTE - ENGINEERING DEMONSTRATION UNIT
CLIENT: NATIONAL RENEWABLE ENERGY LABORATORY
LOCATION: SOUTH POINT,OHIO

DATE: 29-Aug-95
COST ENG: J.SLOMBA

	SCOPE DESCRIPTION	LBR HRS	LABOR $	FLD MTL $	MJR PUR $	SUBCONTRACT $	TOTAL $
1	DEMOLITION / EXPENSE	0	0	-0	0	- 20,000	20,000
	PROCESS AREAS						
2	EQUIPMENT						
	100- WOOD HANDLING	505	20,200	5,000	75,000	0	100,200
	200-PREHYDROLYSIS	642	25,700	2,500	357,600	0	385,800
	300-XYLOSE FERMENTATION	292	11,700	2,200	81,300	200,000	295,200
	400-CELLULASE PRODUCTION	409	16,300	3,500	. 151,700	0	171,500
	500-SSF	804	32,100	7,800	384,700	327,000	751,600
	600-ETHANOL RECOVERY	469	18,800	3,800	226,000	0	248,600
	600-DEHYDRATION	0	0	0	0	0	0
	700-OFF-SITE TANKAGE	137	5,500	1,400	46,800	0	53,700
	800-WASTE TREATMENT	0	0	0	0	0	0
	900-UTILITIES	1,812	72,500	54,900	252,100	580,000	959,500
3	EQUIP. FOUNDATIONS, & SUPPORTS	3,000	120,000	87,000	0	0	207,000
4	PIPING	13,300	532,000	633,000	0	213,000	1,378,000
5	INSTRUMENTATION	4,400	176,000	441,000	0	0	617,000
6	ELECTRICAL	3,300	132,000	110,000	0	0	242,000
7	BUILDINGS	6,300	250,000	450,000	50,000	250,000	1,000,000
8	YARD, SITEWORK, & UNDERGROUND	1,700	68,000	83,000	0	0	151,000
9	OTHER	700	28,000	138,000	0	0	166,000
10	MISCELLANEOUS	0	0	0	0	0	0
	OTHER ALLOWANCES						
	TOTAL DIRECT COST	37,770	1,508,800	2,023,100	1,625,200	1,590,000	6,747,100
	SALES TAX						0
	PREMIUM TIME						52,800
	CONSTRUCTION COST TOTAL						6,799,900
	ENGINEERING / DESIGN						1,360,000
	CONSTRUCTION MANAGEMENT						340,000
	AUTOMATION DESIGN						170,000
	CLIENT ENGINEERING						306,000
	SUBTOTAL						8,975,900
	CONTINGENCY						1,328,400
	rounding						(4,300)
	TOTAL ESTIMATED COST						10,300,000

Table 5-5: EDU Capital Cost Summary

6.0
FINANCIAL PRO FORMA

6.0 Financial Pro Forma

6.1 Ten Year Pro Forma Analysis Overview

Financial analyses were prepared for the two plant sites selected. One set of analyses is at a selected tri-state greenfield site (Millwood WV), the other at an existing plant, such as South Point Ethanol (SPE). These analyses are intended to add a level of detail to the preliminary economics included earlier in this report (See tables 5-1, 5-2, 5-3 and 5-4 in Section 5.0).

These earlier preliminary analyses were based on 1995 costs, with capital charges assumed to be 15.5% of equipment costs, plus startup costs, plus working capital, plus land cost. The pro forma analyses, on the other hand, looks at the economics at a level of detail that would be used by the investors and financial backers of such an enterprise. That is, it considers escalation, financing costs, plant life and cash flow analysis of the facility.

A Base Case scenario was developed for the analyses, based on several assumptions. Tables 6-1A and 6-1B, below, itemize the major assumptions used for each site. The critical financial assumptions at both sites are:

- Interest on Construction Loan 20%
- Interest on Long Term Debt (20 year bond) 10%
- Hurdle Rate for Owner's Equity 14%

A 1995 ethanol selling price was also assumed. This price was chosen at $1.12 per gallon, based on the ethanol price history, as shown on Figure 6-1.

All other major assumptions listed are basically the same as those used in the preliminary economic analyses.

This Base Case was then used to generate an Income Statement and a Cash Flow Analysis for each site. The results show a positive Net Present Value (NPV) of the cash flow at both sites at the assumed selling price. At the minimum acceptable NPV (zero), the selling price for ethanol, in 1995 dollars, calculates to be $1.04 per gallon for the greenfield site and $0.95 per gallon at the existing site.

Further analyses of sensitivities to the various assumed values were then run by calculating the NPV at differing assumed values. The graphs of the change in NPV with these variables were then developed.

The resulting tables and figures are included at the end of this section.

The following discusses each of the major assumptions, with reference to these tables and figures. In order to facilitate understanding these discussions, the following lists the sequence of tables and figures included.

BELCAN ENG'G
PROJECT 315-7324

8/9/95

NREL STUDY OF ETHANOL FROM SAWDUST
SITE - A, GREENFIELD SITE
MAJOR ASSUMPTIONS FOR BASE CASE

BARE PLANT INVESTMENT COST, 1995$		
Process Facilities	$	53,855,466
Offsites & Utilities	$	55,387,013
Total Bare Plant Cost	$	**109,242,479**

CAPITAL COSTS		
Bare Plant Investment, 1995$	$	109,242,479
Land Cost	$	750,000
Startup Costs	$	5,500,000
Working Capital	$	4,860,000
Financial Consulting Fees	$	2,731,250
Interest During Construction	$	36,264,609
Inflationary Costs Till Completion	$	15,794,486
Total Investment at Start of Operations	$	**175,142,825**

CAPACITY AND YIELD	
Full RateDenatured Ethanol Production Rate, Gals/day	92,733
Denatured Ethanol Yield per Ton of Wet Sawdust, Gals/Ton	46.37
Power Generated for export, MW	15.4
Operating Days per Year	333

KEY PRICES		
1995 Wet Sawdust Price, $ Ton	$	10.00
1995 Denatured Ethanol Price, $/Gal		1.12
1995 Export power sale price, $/kwh		0.04

CONSTRUCTION FINANCING	
% Equity Funding During Const'n & Startup	20.00%
Short Term Interest Rate on Construction Loan	20.00%
Construction & Startup Period, Years	3

OPERATIONS FINANCING	
Long Term Debt During Operations	80.00%
Type of Long Term Debt	20 Yr. Bond
Interest on Long-Term Debt	10.00%
Hurdle Rate for NPV of Equity Investment	14.00%
Depreciation Method	Sum of the yrs digits

INFLATION	
Inflation Rate	3.00%
Period of Time Until Construction Start, Years	2

GNPROFRM.XLS
Maj Assump'ns

Table 6-1A: Base Case Assumptions

NREL STUDY OF ETHANOL FROM SAWDUST

SITE - B, EXISTING PLANT SITE
MAJOR ASSUMPTIONS FOR
BASE CASE

BARE PLANT INVESTMENT COST, 1995$		
Process Facilities	$	53,633,817
Offsites & Utilities	$	26,616,183
Total Bare Plant Cost	**$**	**80,250,000**

CAPITAL COSTS		
Bare Plant Investment, 1995$	$	80,250,000
Land Cost	$	750,000
Startup Costs	$	4,050,000
Working Capital	$	3,910,000
Financial Consulting Fees	$	2,006,250
Interest During Construction	$	26,767,872
Inflationary Costs Till Completion	$	11,672,575
Total Investment at Start of Operations	**$**	**129,406,696**

CAPACITY AND YIELD	
Full RateDenatured Ethanol Production Rate, Gals/day	92,733
Denatured Ethanol Yield per Ton of Wet Sawdust, Gals/Ton	46.37
Power Generated for export, MW	0.0
Operating Days per Year	333

KEY PRICES		
1995 Wet Sawdust Price, $ Ton	$	10.00
1995 Denatured Ethanol Price, $/Gal		1.12
1995 Export power sale price, $/kwh		0.04

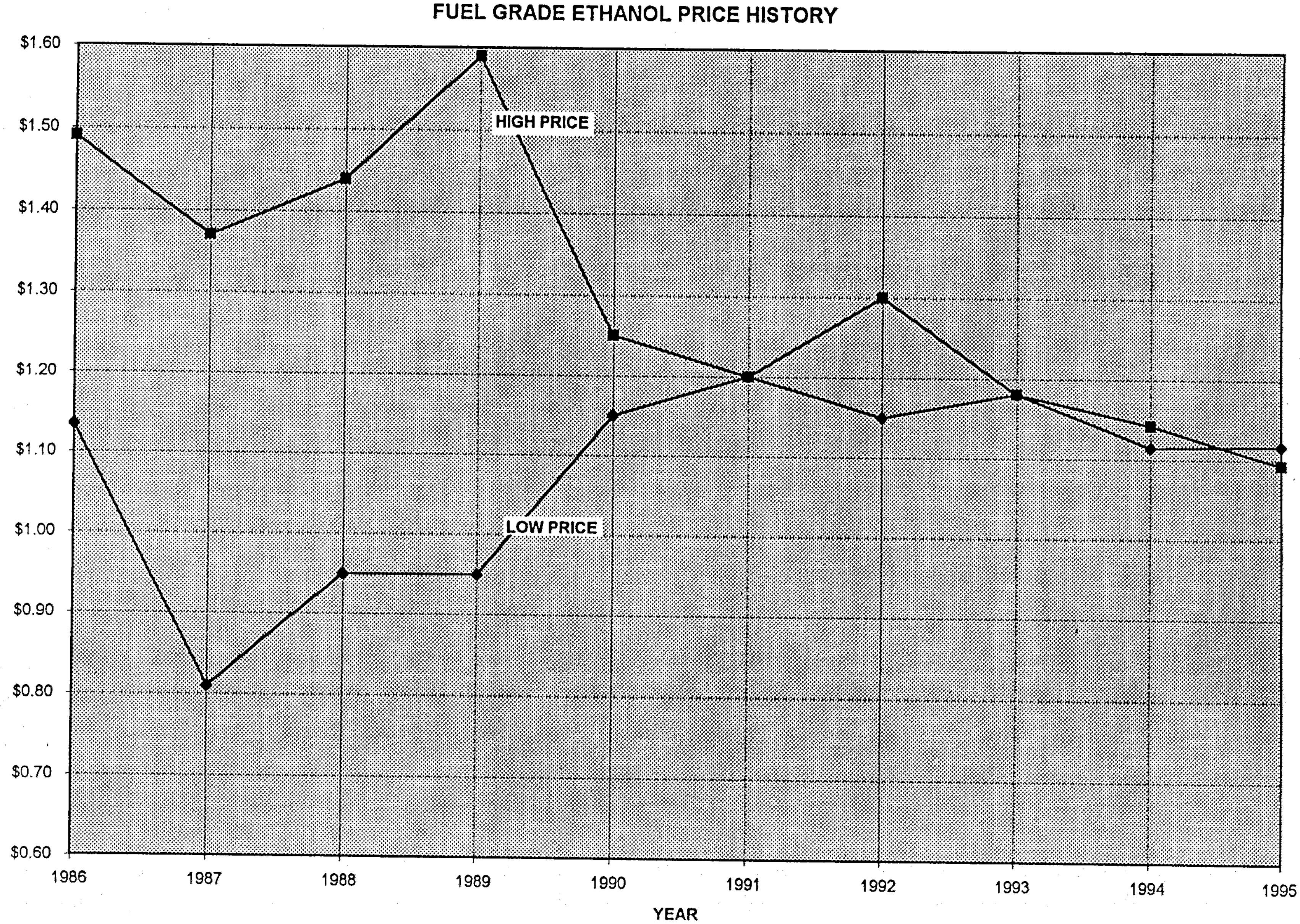
CONSTRUCTION FINANCING	
% Equity Funding During Const'n & Startup	20.00%
Short Term Interest Rate on Construction Loan	20.00%
Construction & Startup Period, Years	3

OPERATIONS FINANCING	
Long Term Debt During Operations	80.00%
Type of Long Term Debt	20 Yr. Bond
Interest on Long-Term Debt	10.00%
Hurdle Rate for NPV of Equity Investment	14.00%
Depreciation Method	Sum of the yrs digits

INFLATION	
Inflation Rate	3.00%
Period of Time Until Construction Start, Years	2

Table 6-1B: Base Case Assumptions

Figure 6-1: Ethanol Price History



YEARS 1994 1995 EXTRAPOLATED FROM SOURCE DATA

SOURCE: *CHEMICAL ECONOMICS HANDBOOK*, STAMFORD RESEARCH, 1995

Subject	Greenfield Site	Existing Site
20 Year NPV Table	Table 6-2A	Table 6-2B
10 Year Income Statement	Table 6-3A	Table 6-3B
10 Year Revenue and Labor	Table 6-4A	Table 6-4B
10 Year (other) Operating Costs	Table 6-5A	Table 6-5B
Capital Investment Calculation	Table 6-6A	Table 6-6B
NPV vs. Hurdle Rate & Ethanol Price	Figure 6-2A	Figure 6-2B
NPV vs. Power Sales Price	Figure 6-3A	N/A
NPV vs. Raw Material Cost	Figure 6-4A	Figure 6-4B
NPV vs. Taxes & Insurance	Figure 6-5A	Figure 6-5B
NPV vs. Percent Debt	Figure 6-6A	Figure 6-6B
NPV vs. Interest Rate	Figure 6-7A	Figure 6-7B
NPV vs. Investment	Figure 6-8A	Figure 6-8B
NPV vs. Construction Interest	Figure 6-9A	Figure 6-9B
NPV vs. Inflation Rate	Figure 6-10A	Figure 6-10B

6.2 Financing and Hurdle Rate

Major assumptions in calculating the Pro Forma Income Statements and NPV's involve the method of financing of such a project. In Belcan's opinion, it is likely that an entity financing such a "first of its kind" project with corporate funds would require a large rate of return (based on the risk). This would negatively impact the project's economics.

A more likely plan would be to have a special purpose corporation set up, whose assets are limited to this project. Such a scenario, known as project financing, utilizes long term contracts for raw materials and product sales to secure loans rather than (non-project) corporate funds. Such contracts would include take or pay clauses and firm prices. Combined with positive PDU and EDU results to prove out the technology, these contracts would make the risk to bond investors acceptable at a reasonable rate of return.

Subsequent plants may obtain better financing, if the initial plant operates successfully and the raw material and ethanol markets can be reasonably forecast. However, the limited supply of sawdust in the studied area make it unlikely that several plants will follow the initial plant in this region. Economics for different regions will vary somewhat with concentrations of sawmills and shipping distances from them to a plant. The economic evaluations included in this report do not attempt to analyze the improved potential possible from a scenario of multiple plants.

The Base Case scenario assumes project financing, with a highly leveraged project. That is, the bulk of the project is funded by long-term bonds at acceptable interest rates (see discussion of interest rates below). The remaining funds (20% in the Base Case) are provided by corporate equity from the owner(s) of the project.

The NPV of a project, in corporate capital budgeting, is normally based on a discount rate that is related to the corporation's incremental cost of capital. The minimum acceptable discount rate to make a project desirable is termed the "Hurdle Rate". The Hurdle Rate is the discounted cash flow rate at which the corporation is willing to invest its own funds. A Hurdle Rate of 14% was assumed for the Base Case. Any positive NPV would be an acceptable investment to equity investors at their chosen Hurdle Rate. Thus, a zero NPV represents the minimum acceptable result which still warrants equity investment at a selected Hurdle Rate. However, with limited equity investment funds and with other projects competing for funds, the higher the NPV, the more likely that funds will be invested. Financing such a project is a complex matter. The amount and type of leverage available and its rate, along with the required discount rate for equity funding can only be accurately assessed for specific participating owners. These factors all need further evaluation by specialists in project financing before committing to a project of this magnitude. The rate assumed (14%) is strictly judgment. A quantitative assessment of the most probable rate is beyond the scope of this study.

Figures 6-2A and 6-2B show the impact of the Hurdle Rate on acceptable sales price for ethanol for the two respective sites studied. These figures indicate that at the minimum acceptable ethanol price, a 2% change in Hurdle Rate changes this price by about $0.02 per gallon at either site.

The greenfield site shows an acceptable NPV at 1995 ethanol prices ranging from $1.02 to $1.14 per gallon over a respective Hurdle Rate range of 10% to 22%, while the existing plant site's range is $0.92 to $1.03 per gallon over the same range of Hurdle Rates.

6.3 Revenues from Ethanol

Figure 6-1, included above, shows the historic prices for fuel grade ethanol. Trending this data to 1995, the current average price would be about $1.12 per gallon.

The fuel grade ethanol market price in the future is a function of many variables, including subsidies, environmental regulations, fuel regulations, crude oil (gasoline) prices, other ethanol raw material prices (mainly corn prices), inflation, automobile engine technology, and competing ethanol uses.

If future fuel grade ethanol prices track gasoline prices, then by utilizing the gasoline price projections provided by NREL to prorate 1995 fuel grade ethanol prices, to the year 2000 (the first year of operation), the ethanol price should be $1.45 per gallon at that future date.

The minimal acceptable 1995 price of ethanol indicated in this pro forma analysis (See Figures 6-2A & 6-2B, at zero NPV and 14% Hurdle Rate) is $1.04 per gallon for the greenfield site and $0.95 per gallon for the existing site. Utilizing the assumed Base Case inflation rate, the market price would have to go to $1.21 per gallon for the greenfield site and $1.10 per gallon for the existing site at the time full production is scheduled to start. After startup it was assumed that this price would continue to escalate along with inflation.

If ethanol prices remain at a flat rate (at $1.12 per gallon as indicated in the historic trend) and other costs escalate with inflation during the 5 years needed to get to full production, the effect can be evaluated by using an assumed $0.97 per gallon 1995 price with Figures 6-2A & 6-2B. Clearly this would not be economical at the greenfield site for the Base Case analyzed. The existing site would, however, still show positive NPV's at a Hurdle Rate of 15% or less. In this scenario, it is however assumed that once full operation begins, ethanol prices will escalate at the assumed inflation rate.

The variability and uncertainty of future ethanol prices represents one of the biggest risks in the project's economics. A study of future market price of ethanol is beyond the scope of this report. If it is believed that ethanol prices will stay flat or decrease in the future, while all other costs inflate at 3% over the 25 years considered, then the program is uneconomical or at best marginal as indicated by this pro forma analysis.

Current negative political climate toward regulation has softened prices, making the Base Case first production year's minimum acceptable price ($1.21 per gallon of ethanol for greenfield and $1.10 per gallon of ethanol for existing site) appear high. However, the climate and regulations that are in existence when this plant goes into service (possibly 5 years from now), could make the indicated minimum prices acceptable.

Another element in ethanol revenues is production rate. The losses shown during the first post start-up year are due to the assumption of 2 month's loss of normal production during this year. This causes about a $5MM swing in cash flow for this early year. An additional 2 months production loss or gain would change the NPV by about $3MM. The Base Case acceptable ethanol price would change by about $0.02 per gallon for every 2 months additional loss or gain in production from the assumed amount during this year.

6.4 Revenue from Power Sales

For the greenfield site, waste gases and lignin are burnt in a high pressure boiler and the steam generated is used to supply all the process steam used. Excess steam is used in a turbine/generator to produce power. All the plant's power needs are provided by the turbine/generator, plus about 15.4 MWe power are available for export.

Published tariffs indicate that such power must be purchased by the local utility. The price paid by the utility is a negotiated price that has a fuel saved element and an avoided capital cost element. Without actually negotiating and utilizing sources with specific expertise in this area, it is not possible to determine a firm, long-term sales price for excess power.

A price of $0.04 per kwh was assumed to be reasonable for the Base Case. Figure 6-3A shows the effect of a change in this assumed price on the NPV for the greenfield site. However, it would be misleading to project the sales revenue downward with a lower negotiated sales price! This design was chosen based on the economics of investing in generating facilities with a 20% annual capital charge on the investment. If a lower than assumed sales price is determined to be more realistic, then the design should be changed to reduce the power generation facilities to produce only the power needed to run the plant. Revenues would be reduced, but so would capital investment. In addition, economics of importing electric power and totally eliminating power generating facilities would need to be evaluated to further reduce investment. Alternative disposal of excess waste gases and lignin would also need to be considered in these cases.

The existing plant site utilizes these waste streams in existing operating and standby boilers, thus displacing present fuel use. The utilization of these existing facilities eliminates the need for the investment in new steam and power generation facilities. An existing site with the power and steam needs of South Point Ethanol is capable of utilizing the heating value of the entire waste streams, without adding any new boilers. The cost of the fuel displaced by burning these streams is assumed to be credited to the BTE plant at $1 per MMBtu, while required imported power cost is assumed to be at $0.045 per kwh.

A consideration that needs to be further evaluated for either site is the technology of combustion of the waste lignin in a boiler. There may be some testing required to confirm the combustion technology for this wet material.

6.5 Raw Material Cost

About 75% of the Raw Material Cost is associated with Sawdust Cost. The total raw material cost represents about 12% of the operating expenses before Federal Income Taxes. The sawdust, therefore, represents somewhat less than 10% of this operating expense.

The assumed Base Case Price for the sawdust is $10.00 per ton. This is based on a study of the value currently assigned to sawdust by sawmills, plus an average shipping cost to the site.

The effect of the cost of sawdust on the NPV, shown on Figures 6-4A and 6-4B, appears to be linear. A $1.00 per ton price difference for wet sawdust appears to change the NPV by about 3 MM dollars for both the greenfield site and the existing plant site. This represents a change of about $0.03 per gallon of ethanol for $1.00 per ton change in green sawdust price.

Figures 6-4A and 6-4B indicate that the Base Case remains acceptable for the greenfield site at a green sawdust cost of as much as $13.50 per ton and for the SPE site at as much as $17.50 per ton. Another consideration regarding sawdust cost is the possibility of getting additional supplies of sawdust that are marginal at the assumed $10 per ton in the Base Case. This would improve the economics via economy of plant scale, but would hurt the economics based on the higher raw material cost. Determination of the optimum combination of price and plant size is beyond the scope of this study.

Other raw materials amount to a much lower percentage of operating expenses. The major other raw material is denaturing gasoline. Gasoline represents about a $0.03 per gallon cost of ethanol in total.

6.6 Chemicals, Utilities, and Disposal Costs

These costs amount to less than 4% of operating expenses. The quantities assumed and the prices used are shown on Tables 6-5Aand 6-5B.

There are no utilities required for the greenfield site, except plant water. The capital costs for this site include all facilities necessary to make the plant self sufficient with respect to all other utilities. The existing plant site, however, imports power in addition to plant water (see discussion of power, above).

6.7 Operating Labor

Labor costs at both sites are based on eight (8) operators for each shift, plus ten (10) staff personnel. At the assumed rates, operating labor costs represent about 5% of operating expenses before income taxes (see Tables 6-4A and 6-4B). Administrative and General expenses are assumed to be 65% of the unburdened labor and maintenance costs at the greenfield site and 35% of these costs at the existing site.

6.8 Local Taxes and Insurance

Local Taxes and Insurance were calculated at 1.5 % percent of depreciated capital costs for the Base Case. This accounts for about 3.0% of operating expenses. The assumed 1.5% rate can vary considerably, based on being able to negotiate with local communities for reduced taxes (especially in early years), as an incentive to create employment in the area. Figures 6-5A and 6-5B show the effect of different Local Taxes and Insurance rates on the NPV.

6.9 Interest

Interest on debt, by itself, is over 25% of the operating expenses. Interest expense is a function of the capital cost (see separate discussion of capital cost), the assumed percentage of debt used in financing, the type of long-term debt, and the interest rate on long-term debt.

For the Base Case, an 80% debt financing with 20 year bonds at 10% was assumed. These assumptions represent very volatile variables. With backing from state, local and/or Federal agencies, these assumptions might be too conservative. With no government or institutional backing for a "first of its kind", high capital cost facility, these assumptions might be very optimistic. Interest rates also vary up and down over time, making it uncertain what the prevailing rates will be at the time of issue of the construction loan or the long-term loan.

There is an underlying assumption, in the selection of the type of debt, that no debt is repaid until the 20th year. This will probably require that the owners provide a "Sinking Fund" that will assure debtors that cash to repay the debt will be present at the end of the 20 years. Assuming this "Sinking Fund" earns at the hurdle rate, this would have no effect on the economics.

The profitability, as a function of interest cost, is effected by the interest rate, the amount of debt financing, and the relation of the interest rate to the equity hurdle rate. Figures 6-6A and 6-6B show the variability of NPV with interest rates at various amounts of debt financing and Figures 6-7A and 6-7B show the effect of long term debt interest rates on NPV at various ethanol prices.

For the greenfield site Figure 6-6A shows that a debt can be as low as 52% and still show acceptable economics for the Base Case; at 80% debt financing acceptable economics are indicated up to about 12% interest rate. At the existing plant site, the minimum acceptable percent debt financing is about 22% debt and the maximum acceptable interest rate at 80% debt is indicated to be 16% (see Figure 6-6B).

Figure 6-7A shows that a Base Case greenfield plant has acceptable economics at $0.91 per gallon 1995 ethanol price with a 6% interest rate and at $1.15 per gallon at 13% interest. For the existing plant site, these numbers would be $0.85 per gallon at 6% and $1.03 per gallon at 13% interest based on Figure 6-7B.

6.10 Depreciation

Accelerated depreciation, using sum of the years depreciation method, for a 20 year plant life was applied to calculate depreciation. Depreciation accounts for over 20% of operating expenses before taxes, over the first 10 years of operation. This has a major impact on Federal Income Taxes and Net Income. However, since depreciation is not a cash expense, its only effect on cash flow is through its reduction in Federal Income Taxes. In effect, the accelerated depreciation defers taxes until later years and in this manner is very important to NPV in terms of cash flow. If accelerated depreciation cannot be taken, the profitability of the plant would be negatively effected by an appreciable amount.

The 20 year life of the plant is tied to assuming a 20 year loan and a 20 year production of cash flow. It is unlikely that an investment of this size can be economical with only a ten year plant life. The contribution to NPV for the Base Case from the second 10 years of operation is very appreciable.

6.11 Capital Costs

Capital Costs have a major impact on the profitability. Figures 6-8A and 6-8B show how the NPV varies at various ethanol selling prices, with various bare 1995 plant investment costs. For the $110MM greenfield site 1995 bare plant cost plus land, at the Base Case assumed conditions, Figure 6-8A shows an acceptable NPV at a 1995 ethanol selling price of $1.04 per gallon for the greenfield site. If the bare plant cost, at this site were to change by $10MM, this price would change by about $0.07 per gallon.

For the existing plant site, the 1995 bare plant investment plus land is $81MM. Figure 6-8B shows the minimum acceptable price is about $0.95 per gallon and a $10MM change in bare plant cost also results in about a $0.07 per gallon change in ethanol price.

The factors that make up the investment costs are shown on Tables 6-6A and 6-6B. Essentially all of the inputs leading to the bare 1995 plant investment cost result from Belcan's Process and Estimating calculations and are discussed elsewhere. The major difference in plant costs between the greenfield site and the existing site is due to the use of existing facilities to convert waste streams to useable energy. This is reflected in the additional $29MM bare cost in offsite and utility costs for the greenfield site. The underlying assumption in siting at SPE plant is that it is already operating at full capacity and has essentially no excess facilities, except those that are standby during full operation. A case where SPE is not operating at full capacity and has facilities available to retrofit for sawdust conversion was not included in this study.

The assumptions which convert the bare plant cost to total investment include financing costs, startup costs, working capital required, debt drawdown rate during construction, the debt/equity ratio during construction, the construction period, interest rates on the construction loan, land, and inflation. A 20% interest rate for a short term loan, such as this, was assumed for the Base Case. The high rate reflects the three year term of the loan and risk of completion and successful operation of this "first of its kind" plant. Figures 6-9A and 6-9B show the effect of different interest rates on construction loans. An interest rate of 15%, instead of 20%, on such construction loans would save $9MM to $12MM in investment and, therefore, might reduce the acceptable ethanol sales price by as much as $0.07 to $0.09 per gallon. Such reduction could be possible with government financial support or such support from product purchasers, and/or raw material suppliers.

A shortening of the construction period could also reduce the total investment cost by lowering interest during construction. However, Belcan believes the construction period assumed is reasonable for this size plant. Fast-tracking is possible, but there is a cost associated with this.

A further consideration toward capital cost reduction is the utilization of the economies of scale. Very roughly, a $70MM to $90MM added investment would result in about a 100% increase in capacity. Even without utilizing scaling benefits on operating expenses, this could reduce the acceptable sales price of ethanol by about $0.05 to $0.09 per gallon.

6.12 Inflation

A 3% per year inflation factor was assumed for the Base Case. This factor was applied to all revenues and expenses, except interest on debt, power and carbon dioxide sales price (assumed to be a long-term contracts), depreciation, and local taxes and insurance. Capital costs were also inflated by this factor during the construction period.

As a result, since some large costs (such as interest and debt repayment) are not affected by inflation during the 20 years of operation, profitability increases with inflation. Figures 6-10A and 6-10B show that a 1% inflation rate change results in about an $5.5MM change in NPV for the greenfield site and about $6MM change for the existing plant site. If the assumed 3% inflation rate turned out to actually be 2%, then the minimum acceptable ethanol selling price would be about $0.04 per gallon more for both sites. Without any escalation of any costs or revenues, the minimum acceptable ethanol price would calculate to be $1.14 per gallon for the greenfield site and $1.06 per gallon for the SPE site.

It should be noted that if long-term contracts for ethanol sales are utilized, inflation adjusters should be sought or else the benefits of inflation on the pro forma economics would be lost. It should also be noted (as discussed in Revenues, above) if market projections of ethanol prices do not support the assumption that its price can keep pace with inflation, the economics, as shown herein, would be adversely effected.

GREENFIELD SITE EXHIBITS TO PRO FORMA ANALYSIS

BASE CASE
NPV CALCULATION
SITE A -- GREENFIELD SITE

Year	Cash Flow With 20 Yr Loan	
-2	$	(7,064,364)
-1	$	(14,193,898)
0	$	(13,121,974)
1	$	1,436,834
2	$	8,443,032
3	$	9,222,271
4	$	10,003,109
5	$	10,790,091
6	$	11,587,510
7	$	12,387,205
8	$	13,194,248
9	$	14,009,013
10	$	14,830,658
11	$	14,911,133
12	$	12,741,168
13	$	12,935,948
15	$	13,344,714
16	$	13,558,953
17	$	13,780,149
18	$	14,011,413
19	$	14,249,518
20	$	(116,709,672)
HURDLE RATE		14.0%
NPV @ 20 YRS	$	11,891,082

BELCAN ENG'G
PROJECT 315-7324

NREL STUDY OF ETHANOL FROM SAWDUST

8/11/95

PROFORMA BASE CASE
10 YEAR INCOME STATEMENT -- SITE A
GREENFIELD SITE

ASSUMPTIONS

Type of Long Term Debt	20 Yr. Bond
Percent Debt	80%
Interest Rate on RemainingDebt	10%
Financial Consultant Cost as a % of Erected Cost	2.5%
Local Taxes and Isurance as Funct'n of Depreciated Plant Value	1.5%
State, PlusFederal Income Tax Rate	40.0%
Maintenance as a percent of total erected cost	3.0%
A& G Expense as a % of Direct Operator Labor , Plus Maintenance	65.0%
Depreciation Method	Sum of the yrs digits

YEAR	1	2	3	4	5	6	7	8	9	10
Depreciation	9.52%	9.05%	8.67%	8.10%	7.62%	7.14%	6.67%	6.19%	5.71%	5.24%
Debt Repayment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Remaining Debt	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944	$ 137,520,944
Interest Rate on RemainingDebt	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094	$13,752,094

	PRO FORMA DATA FOR OPERATION ENDING IN YEAR:										10 YEAR
	1	2	3	4	5	6	7	8	9	10	TOTAL
REVENUE	$ 37,725,709	$ 47,388,063	$ 48,627,063	$ 49,903,063	$ 51,217,063	$ 52,571,063	$ 53,966,063	$ 55,402,063	$ 56,881,063	$ 58,405,063	$ 512,086,275
OPERATING EXPENSES											
RAW MATERIALS	$ 7,745,000	$ 9,766,000	$ 10,060,000	$ 10,362,000	$ 10,674,000	$ 10,992,000	$ 11,322,000	$ 11,663,000	$ 12,012,000	$ 12,373,000	$ 106,969,000
CHEMICALS	$ 1,956,477	$ 2,467,103	$ 2,541,116	$ 2,617,350	$ 2,695,870	$ 2,776,747	$ 2,860,049	$ 2,945,850	$ 3,034,226	$ 3,125,253	$ 27,020,042
DISPOSAL	$ 187,489	$ 236,422	$ 243,515	$ 250,820	$ 258,345	$ 266,095	$ 274,078	$ 282,301'	$ 290,770	$ 299,493	$ 2,589,329
UTILITIES	$ 37,877	$ 47,762	$ 49,195	$ 50,671	$ 52,191	$ 53,757	$ 55,369	$ 57,030	$ 58,741	$ 60,504	$ 523,097
OPERATOR LABOR	$ 2,568,000	$ 2,646,000	$ 2,724,000	$ 2,807,000	$ 2,891,000	$ 2,977,000	$ 3,067,000	$ 3,158,000	$ 3,253,000	$ 3,351,000	$ 29,442,000
MAINTENANCE	$ 3,825,604	$ 3,940,373	$ 4,058,584	$ 4,180,341	$ 4,305,752	$ 4,434,924	$ 4,567,972	$ 4,705,011	$ 4,846,161	$ 4,991,546	$ 43,856,268
ADMIN & GENERAL EXPENSES	$ 3,637,815	$ 3,747,380	$ 3,859,183	$ 3,975,532	$ 4,094,704	$ 4,217,218	$ 4,344,044	$ 4,473,912	$ 4,608,246	$ 4,746,677	$ 41,704,712
INTEREST	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 13,752,094	$ 137,520,944
DEPRECIATION	$ 15,774,813	$ 14,986,072	$ 14,197,331	$ 13,408,591	$ 12,619,850	$ 11,831,109	$ 11,042,369	$ 10,253,628	$ 9,464,888	$ 8,676,147	$ 122,254,798
LOCAL TAXES & INSURANCE	$ 2,578,518	$ 2,341,896	$ 2,117,104	$ 1,904,144	$ 1,703,016	$ 1,513,718	$ 1,336,251	$ 1,170,616	$ 1,016,811	$ 874,838	$ 16,556,912
TOTAL OPERAT'G EXP. BEFORE FIT	$ 52,063,687	$ 53,931,102	$ 53,602,123	$ 53,308,544	$ 53,046,822	$ 52,814,662	$ 52,621,227	$ 52,461,443	$ 52,336,938	$ 52,250,552	$ 528,437,101
TAXABLE INC. PRE-PRIOR YEAR LOSSES	$ (14,337,978)	$ (6,543,040)	$ (4,975,060)	$ (3,405,481)	$ (1,829,759)	$ (243,599)	$ 1,344,836	$ 2,940,620	$ 4,544,125	$ 6,154,511	$ (16,350,826)
PRIOR YEAR TAX LOSSES USED	$ -	$ -	$ -	$ -	$ -	$ -	$ (1,344,836)	$ (2,940,620)	$ (4,544,125)	$ (6,154,511)	$ (14,984,092)
TAXABLE INCOME	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
STATE & FEDERAL INCOME TAXES	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
NET INCOME	$ (14,337,978)	$ (6,543,040)	$ (4,975,060)	$ (3,405,481)	$ (1,829,759)	$ (243,599)	$ 1,344,836	$ 2,940,620	$ 4,544,125	$ 6,154,511	$ (16,350,826)
CASH FLOW	$ 1,436,834	$ 8,443,032	$ 9,222,271	$ 10,003,109	$ 10,790,091	$ 11,587,510	$ 12,387,205	$ 13,194,248	$ 14,009,013	$ 14,830,658	$ 105,903,972

Table 6.3A: 10 Year Income Statement

GNPROFRM.XLS
INC STATET

BELCAN ENG'G GROUP
PROJECT 315-7324

8/11/95

NREL STUDY OF ETHANOL PRODUCTION FROM SAWDUST

BASE CASE 10 YEAR REVENUE AND LABOR DATA -- SITE A, GREENFIELD SITE

ASSUMPTIONS	
Full RateDenatured Ethanol Production Rate, Gals/day	92,733
1995 Denatured Ethanol Price, $/Gal	1.12
Power Generated for export, MW	15.40
1995 Export power sale price, $/kwh	0.040
Carbon Dioxide Production Rate, lbs./Hr	23,688
Carbon Dioxude Sales, % of Production	50%
1995 Carbon Dioxide Sales Price, $/Ton	7.0
Operators & foremen per shift	8
Day Supervisors, Mgrs & A&G personnel	10
1995 Operator Hourly Rate, W/Burdens, $/Hr	24.4
1995 Other Personnel Hourly Rate, W/Burdens, $/Hr	27.6

	1	2	3	4	5	6	7	8	9	10
Days Per Year Operation	272	333	333	333	333	333	333	333	333	333
Inflation Factor	1.16	1.19	1.23	1.27	1.30	1.34	1.38	1.43	1.47	1.51

	PRO FORMA DATA FOR OPERATION ENDING IN YEAR:										10 YEAR TOTAL
REVENUES	1	2	3	4	5	6	7	8	9	10	
Gal./Year Ethanol Produced	25,223,303	30,880,000	30,880,000	30,880,000	30,880,000	30,880,000	30,880,000	30,880,000	30,880,000	30,880,000	303,143,303
$/Gal. Ethanol Price FOB Plant	$ 1.30	$ 1.34	$ 1.38	$ 1.42	$ 1.46	$ 1.51	$ 1.55	$ 1.60	$ 1.64	$ 1.69	$ 1.49
Ethanol Revenues	$ 32,750,000	$ 41,297,000	$ 42,536,000	$ 43,812,000	$ 45,126,000	$ 46,480,000	$ 47,875,000	$ 49,311,000	$ 50,790,000	$ 52,314,000	$ 452,291,000
KWH/YR Exported	100,531,200	123,076,800	123,076,800	123,076,800	123,076,800	123,076,800	123,076,800	123,076,800	123,076,800	123,076,800	1,208,222,400
$/KWH Export Power Selling Price	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.046	$ 0.05
Export Power Revenues	$ 4,662,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 5,707,000	$ 56,025,000
Tons/Year Carbon Dioxide Sold	38,658	47,328	47,328	47,328	47,328	47,328	47,328	47,328	47,328	47,328	464,610
$/Ton Carbon Dioxide Selling Price	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.115	$ 8.11
Carbon Dioxide Revenues	$ 313,709	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 384,063	$ 3,770,275
Total Revenues	$ 37,725,709	$ 47,388,063	$ 48,627,063	$ 49,903,063	$ 51,217,063	$ 52,571,063	$ 53,966,063	$ 55,402,063	$ 56,881,063	$ 58,405,063	$ 512,086,275

	PRO FORMA DATA FOR OPERATION ENDING IN YEAR:										10 YEAR TOTAL
LABOR	1	2	3	4	5	6	7	8	9	10	
No. of operators per shift	8	8	8	8	8	8	8	8	8	8	8
Cost per Operator-Hr W/Burdens	$ 28.30	$ 29.15	$ 30.02	$ 30.92	$ 31.85	$ 32.80	$ 33.79	$ 34.80	$ 35.85	$ 36.92	$ 31.55
Total Operator Expenses	$ 1,929,000	$ 1,987,000	$ 2,046,000	$ 2,108,000	$ 2,171,000	$ 2,236,000	$ 2,303,000	$ 2,372,000	$ 2,443,000	$ 2,517,000	$ 22,112,000
No.Supervisory, Mgt. & Admin	10	10	10	10	10	10	10	10	10	10	10
Cost per Operator-Hr W/Burdens	$ 32	$ 33	$ 34	$ 35	$ 36	$ 37	$ 38	$ 39	$ 41	$ 42	$ 35
Total Sup'n, Mgt & Admin Exp.	$ 639,000	$ 659,000	$ 678,000	$ 699,000	$ 720,000	$ 741,000	$ 764,000	$ 786,000	$ 810,000	$ 834,000	$ 7,330,000
Total Labor Expenses	$ 2,568,000	$ 2,646,000	$ 2,724,000	$ 2,807,000	$ 2,891,000	$ 2,977,000	$ 3,067,000	$ 3,158,000	$ 3,253,000	$ 3,351,000	$ 29,442,000

NREL STUDY OF ETHANOL FROM SAWDUST

BASE CASE

10 YR. DATA FOR RAW MAT'L, CHEM'S, DISPOSAL AND UTIL. COSTS

SITE - A, GREENFIELD SITE

ASSUMPTIONS		
Denatured Ethanol Yield per Ton of Wet Sawdust, Gals/Ton	46.4	
1995 Wet Sawdust Price, $ Ton	10.00	
Gasoline Required per gal per quantity Denatured Ethanol Sold, Gals/Gal	5.11%	
1995 Gasoline additive Price, $/Gal	0.75	
1995 CIP Chemicals, $/Yr	50,000	
1995 Boiler Chemicals, $/Yr	120,000	
1995 Cooling water Chemicals, $/yr	480,000	
	QTY T/YR	1995 $/Ton
Acid	5,369	82.6
Ammonia	2,541	110.0
Corn Steep Liquor	293	242.0
Nutrients	84	272.8
Antifoam	17	536.0
Glucose	258	1,166.0
Diesel	2,500	281.8
Dewatering Cemicals	100	200.0
Makeup Water	1,859,627	0.0215
Solids for Disposal	99	2,000

		PRO FORMA DATA FOR OPERATION ENDING IN YEAR:										10 YEAR TOTAL
		1	2	3	4	5	6	7	8	9	10	
RAW MATERIALS	UNITS											
Wet Sawdust quantity	Tons/Yr	544,000	666,000	666,000	666,000	666,000	666,000	666,000	666,000	666,000	666,000	6,538,000
Delivered charge rate at Tipper	$/Ton	$ 11.59	$ 11.94	$ 12.30	$ 12.67	$ 13.05	$ 13.44	$ 13.84	$ 14.26	$ 14.69	$ 15.13	$ 13.32
Sawdust cost	$/Yr	$ 6,306,000	$ 7,952,000	$ 8,191,000	$ 8,437,000	$ 8,690,000	$ 8,950,000	$ 9,219,000	$ 9,496,000	$ 9,780,000	$ 10,074,000	$ 87,095,000
Denaturing Gasoline	Gal/Yr	1,225,225	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	14,725,225
Gasoline Price	$/Gal	$ 0.87	$ 0.90	$ 0.92	$ 0.95	$ 0.98	$ 1.01	$ 1.04	$ 1.07	$ 1.10	$ 1.13	$ 1.00
Denaturing Gasoline Cost	$/Yr	$ 1,065,000	$ 1,343,000	$ 1,384,000	$ 1,425,000	$ 1,468,000	$ 1,512,000	$ 1,557,000	$ 1,604,000	$ 1,652,000	$ 1,702,000	$ 14,712,000
Nutrients	T/YR	69	84	84	84	84	84	84	84	84	84	825
Price	$/T	$ 316	$ 326	$ 336	$ 346	$ 356	$ 367	$ 378	$ 389	$ 401	$ 413	$ 365
Cost	$/Yr	$ 22,000	$ 27,000	$ 28,000	$ 29,000	$ 30,000	$ 31,000	$ 32,000	$ 33,000	$ 34,000	$ 35,000	$ 301,000
Corn Steep Liquor	T/YR	239	293	293	293	293	293	293	293	293	293	2,876
Price	$/T	$ 281	$ 289	$ 298	$ 307	$ 316	$ 325	$ 335	$ 345	$ 355	$ 366	$ 322
Cost	$/Yr	$ 67,000	$ 85,000	$ 87,000	$ 90,000	$ 93,000	$ 95,000	$ 98,000	$ 101,000	$ 104,000	$ 107,000	$ 927,000
Glucose	T/YR	211	258	258	258	258	258	258	258	258	258	2,533
Price	$/T	$ 1,352	$ 1,392	$ 1,434	$ 1,477	$ 1,521	$ 1,567	$ 1,614	$ 1,662	$ 1,712	$ 1,764	$ 1,553
Cost	$/Yr	$ 285,000	$ 359,000	$ 370,000	$ 381,000	$ 393,000	$ 404,000	$ 416,000	$ 429,000	$ 442,000	$ 455,000	$ 3,934,000
TOTAL RAW MATERIAL COSTS		$ 7,745,000	$ 9,766,000	$ 10,060,000	$ 10,362,000	$ 10,674,000	$ 10,992,000	$ 11,322,000	$ 11,663,000	$ 12,012,000	$ 12,373,000	$ 106,042,000
CHEMICALS												
Acid		$ 419,937	$ 529,538	$ 545,424	$ 561,786	$ 578,640	$ 595,999	$ 613,879	$ 632,296	$ 651,264	$ 670,802	$ 5,799,566
Ammonia		$ 264,672	$ 333,750	$ 343,762	$ 354,075	$ 364,697	$ 375,638	$ 386,907	$ 398,514	$ 410,470	$ 422,784	$ 3,655,269
Antifoam		$ 8,628	$ 10,880	$ 11,207	$ 11,543	$ 11,889	$ 12,246	$ 12,613	$ 12,992	$ 13,381	$ 13,783	$ 119,161
Diesel		$ 628,807	$ 792,921	$ 816,709	$ 841,210	$ 866,446	$ 892,440	$ 919,213	$ 946,789	$ 975,193	$ 1,004,449	$ 8,684,175
Dewatering Cemicals		$ 18,938	$ 23,881	$ 24,597	$ 25,335	$ 26,095	$ 26,878	$ 27,685	$ 28,515	$ 29,371	$ 30,252	$ 261,548
CIP Chemicals		$ 47,346	$ 59,703	$ 61,494	$ 63,339	$ 65,239	$ 67,196	$ 69,212	$ 71,288	$ 73,427	$ 75,629	$ 653,871
Boiler Chemicals		$ 113,630	$ 143,286	$ 147,585	$ 152,012	$ 156,573	$ 161,270	$ 166,108	$ 171,091	$ 176,224	$ 181,511	$ 1,569,290
Cooling water Chemicals		$ 454,519	$ 573,145	$ 590,339	$ 608,050	$ 626,291	$ 645,080	$ 664,432	$ 684,365	$ 704,896	$ 726,043	$ 6,277,161
TOTAL CHEMICALS		$ 1,956,477	$ 2,467,103	$ 2,541,116	$ 2,617,350	$ 2,695,870	$ 2,776,747	$ 2,860,049	$ 2,945,850	$ 3,034,226	$ 3,125,253	$ 27,020,042
UTILITIES												
Makeup Water		$ 37,877	$ 47,762	$ 49,195	$ 50,671	$ 52,191	$ 53,757	$ 55,369	$ 57,030	$ 58,741	$ 60,504	$ 523,097
TOTAL UTILITIES		$ 37,877	$ 47,762	$ 49,195	$ 50,671	$ 52,191	$ 53,757	$ 55,369	$ 57,030	$ 58,741	$ 60,504	$ 523,097
DISPOSAL												
Solids Disposal		$ 187,489	$ 236,422	$ 243,515	$ 250,820	$ 258,345	$ 266,095	$ 274,078	$ 282,301	$ 290,770	$ 299,493	$ 2,589,329
TOTAL DISPOSAL		$ 187,489	$ 236,422	$ 243,515	$ 250,820	$ 258,345	$ 266,095	$ 274,078	$ 282,301	$ 290,770	$ 299,493	$ 2,589,329

NREL STUDY OF ETHANOL PRODUCTION FROM SAWDUST

BASE CASE
CAPITAL INVESTMENT CALCULATION
SITE A -- GREENFIELD SITE

Table 6-6A: Capital Investment

ASSUMPTIONS

Inflation Rate	3.00%		
Short Term Interest Rate on Construction Loan	20.00%		
% Equity Funding During Const'n & Startup	20.00%		
Hurdle Rate for NPV of Equity Investment	14.00%		
Long Term Debt During Operations	80.00%		
Interest on Long-Term Debt	10.00%		
Period of Time Until Construction Start, Years	2		
Construction & Startup Period, Years	3		
Construction Year	1	2	3
% of Erection funds Drawn	25%	50%	25%

PROCESS UNITS COSTS IN 1995 $	Equipment Purchase Cost	Erected Equipment Cost	Piping	Instruments	Electrical	Sub-Total	In-house & Outside Engineering, & Automation	Construction Management	Contingency & Rounding	Total Cost	% of Total Plant
Wood Handling	$ 701,000	$ 1,113,714	$ 439,863	$ 267,762	$ 177,674	$ 1,999,012	$ 527,835	$ 105,040	$ 312,589	$ 2,944,477	2.7%
Prehydrolysis	$ 6,666,600	$ 9,913,421	$ 4,183,150	$ 2,546,447	$ 1,689,702	$ 18,332,720	$ 4,840,718	$ 963,314	$ 2,866,716	$ 27,003,467	24.7%
Xylose Fermentation	$ 322,800	$ 1,690,697	$ 202,550	$ 123,300	$ 81,816	$ 2,098,363	$ 554,069	$ 110,261	$ 328,124	$ 3,090,817	2.8%
Cellulase Production	$ 448,500	$ 1,066,442	$ 281,424	$ 171,314	$ 113,676	$ 1,632,856	$ 431,152	$ 85,800	$ 255,332	$ 2,405,141	2.2%
SSF	$ 1,232,600	$ 5,092,271	$ 773,430	$ 470,817	$ 312,412	$ 6,648,931	$ 1,755,637	$ 349,376	$ 1,039,704	$ 9,793,647	9.0%
Ethanol Recovery	$ 1,261,600	$ 2,030,940	$ 791,627	$ 481,894	$ 319,762	$ 3,624,224	$ 956,969	$ 190,439	$ 566,726	$ 5,338,358	4.9%
Dehydration	$ 790,200	$ 1,228,552	$ 495,834	$ 301,833	$ 200,282	$ 2,226,501	$ 587,903	$ 116,994	$ 348,161	$ 3,279,560	3.0%
TOTAL PROCESS UNITS	$ 11,423,300	$ 22,136,036	$ 7,167,878	$ 4,363,367	$ 2,895,325	$ 36,562,607	$ 9,654,282	$ 1,921,224	$ 5,717,352	$ 53,855,466	49.3%
OFFSITES & UTILITIES											
Site Preparation	$ -	$ 250,000	$ -	$ -	$ -	$ 250,000	$ 37,864	$ 7,535	$ 22,424	$ 317,823	0.3%
Yard Facilities & Roads	$ -	$ 3,434,473	$ -	$ -	$ -	$ 3,434,473	$ 520,176	$ 103,516	$ 308,053	$ 4,366,219	4.0%
Buildings	$ 150,000	$ 3,092,212	$ 45,729	$ 27,840	$ 18,473	$ 3,184,255	$ 482,279	$ 95,975	$ 285,610	$ 4,048,118	3.7%
Tankage	$ 252,500	$ 940,989	$ 76,978	$ 46,864	$ 31,097	$ 1,095,927	$ 165,986	$ 33,032	$ 98,299	$ 1,393,243	1.3%
Waste Treatment	$ 422,600	$ 1,285,131	$ 128,835	$ 78,434	$ 52,045	$ 1,544,445	$ 233,918	$ 46,550	$ 138,528	$ 1,963,441	1.8%
Utilities	$ 854,270	$ 2,892,501	$ 260,435	$ 158,551	$ 105,207	$ 3,416,695	$ 517,484	$ 102,980	$ 306,458	$ 4,343,617	4.0%
Boiler & Power Generation	$ 7,688,430	$ 25,923,955	$ 2,343,914	$ 1,426,963	$ 946,865	$ 30,641,699	$ 4,640,911	$ 923,552	$ 2,748,390	$ 38,954,552	35.7%
TOTAL OFFSITES & UTILITIES	$ 9,367,800	$ 37,819,261	$ 2,855,891	$ 1,738,652	$ 1,153,688	$ 43,567,493	$ 6,598,618	$ 1,313,140	$ 3,907,761	$ 55,387,013	50.7%
TOTAL ERECTION COSTS	$ 20,791,100	$ 59,955,297	$ 10,024,000	$ 6,102,000	$ 4,049,000	$ 80,130,100	$ 16,257,100	$ 3,235,200	$ 9,627,600	$ 109,250,000	
									Land	$ 750,000	
									1995 Project Cost Check	$ 110,000,000	

INVESTMENT SCHEDULE SUMMARY	Construction Year 1	2	3	TOTAL
Erection Costs	$ 27,312,500	$ 54,625,000	$ 27,312,500	$ 109,250,000
Startup Costs	$ -		$ 5,500,000	$ 5,500,000
Interest Costs	$ 2,500,453	$ 10,322,136	$ 20,621,022	$ 33,443,610
Depreciable Costs	$ 29,812,953	$ 64,947,136	$ 53,433,522	$ 148,193,610
Land Cost	$ 750,000	$ -	$ -	$ 750,000
Financial Consultant Cost	$ 2,731,250			$ 2,731,250
Working Capital	$ -	$ -	$ 4,860,000	$ 4,860,000
Investment for the Yr ($1995)	$ 33,294,203	$ 64,947,136	$ 58,293,522	$ 156,534,860
Inflation Factor	1.06	1.09	1.13	
Infl. Adj'd Investment for Yr	35,321,819	70,969,489	65,609,872	
Infl. Adj'd Cummul. Investment	$ 35,321,819	$ 106,291,308	$ 171,901,180	
Debt for the Year	$ 28,257,456	$ 56,775,591	$ 52,487,898	
Equity for the Year	$ 7,064,364	$ 14,193,898	$ 13,121,974	
Cummulative Debt	$ 28,257,456	$ 85,033,047	$ 137,520,944	
Cummulative Equity	$ 7,064,364	$ 21,258,262	$ 34,380,236	

SENSITIVITY OF NPV WITH HURDLE RATES AT VARIOUS ETHANOL PRICES

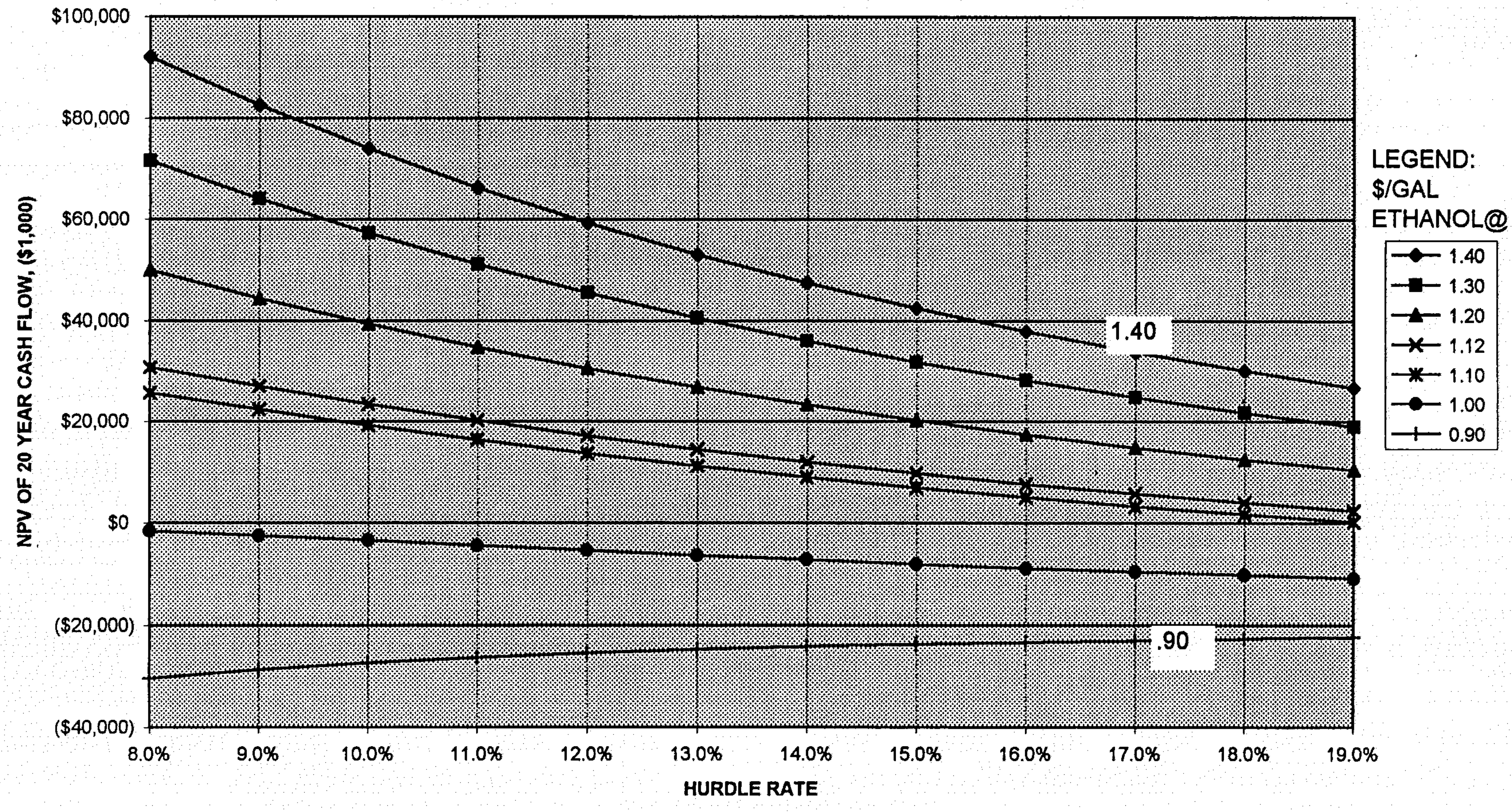


Figure 6-2A: Hurdle Rate

Capital HURDLE RATE

SENSITIVITY OF NPV TO ELECTRIC POWER SELLING PRICE

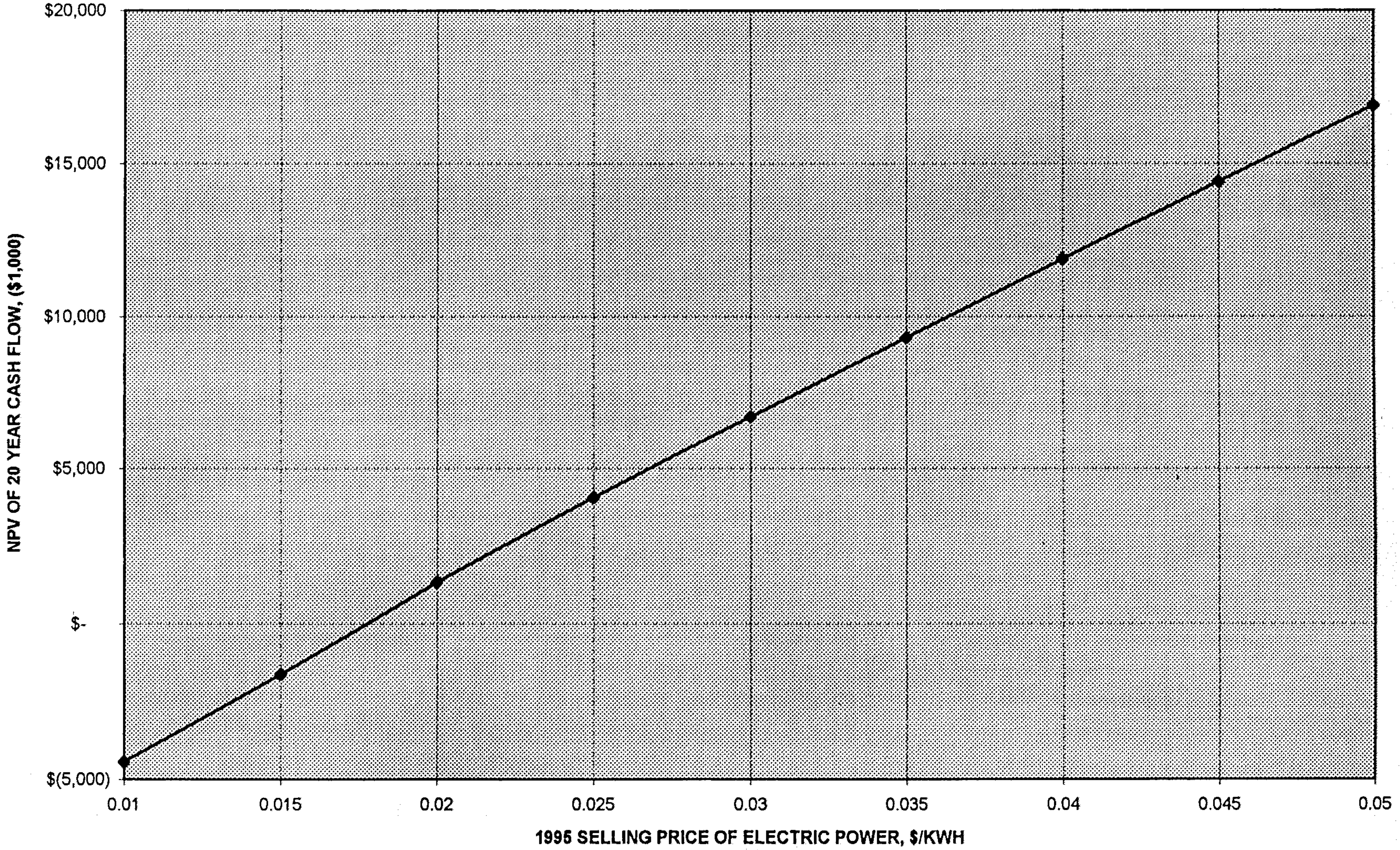


Figure 6-3A: Electric Power

Capital ELECTRIC POWER

SENSITIVITY OF NPV TO SAWDUST DELIVERED PRICE

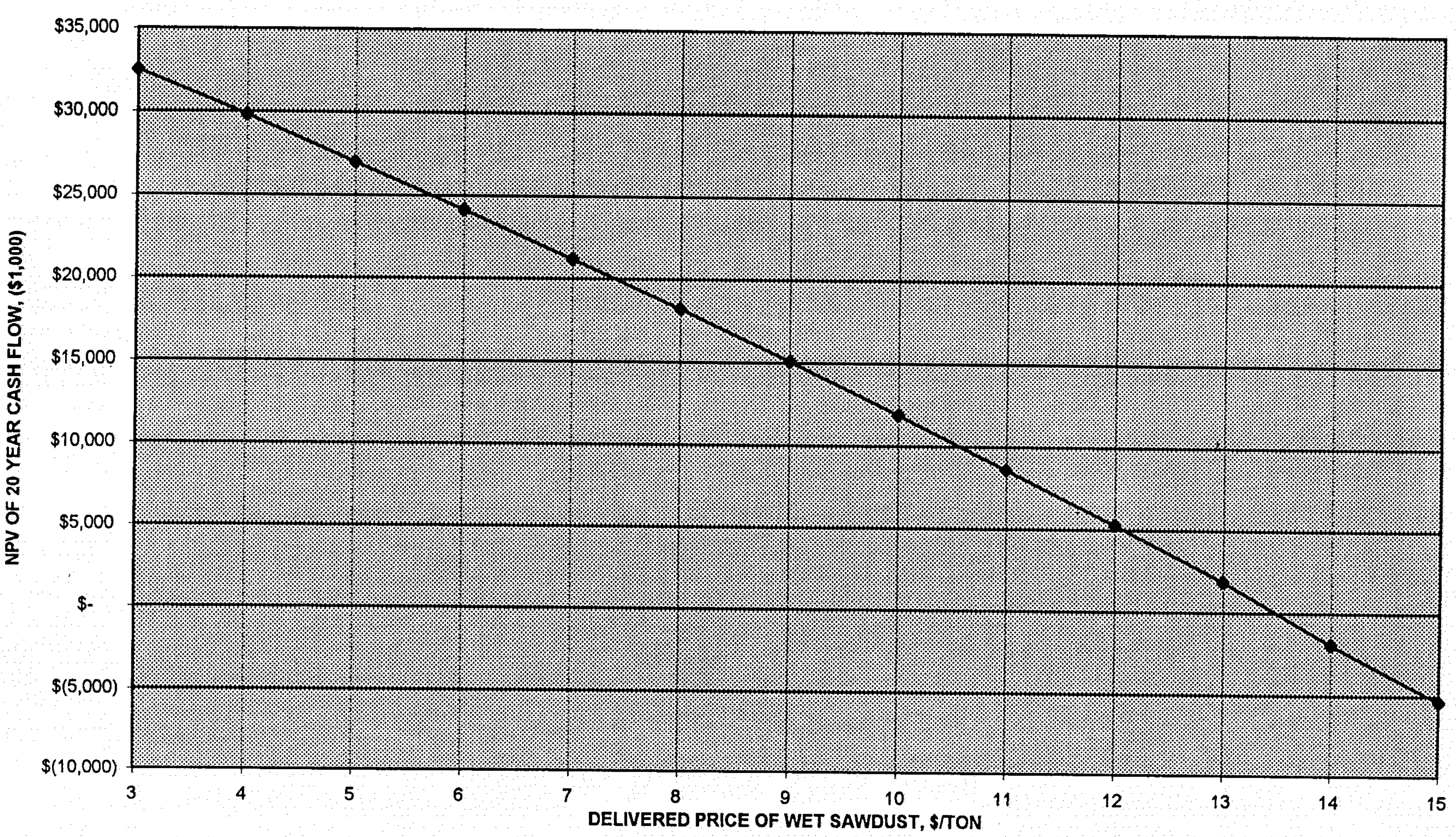


Figure 6-4A: Raw Material

Capital RAW MATERIAL

BELCAN ENG'G
PROJECT 315-7324

NREL STUDY OF ETHANOL FROM SAWDUST

SITE - A, GREENFIELD SITE

8/11/95

EFFECT OF LOCAL TAXES & INSURANCE ON NPV

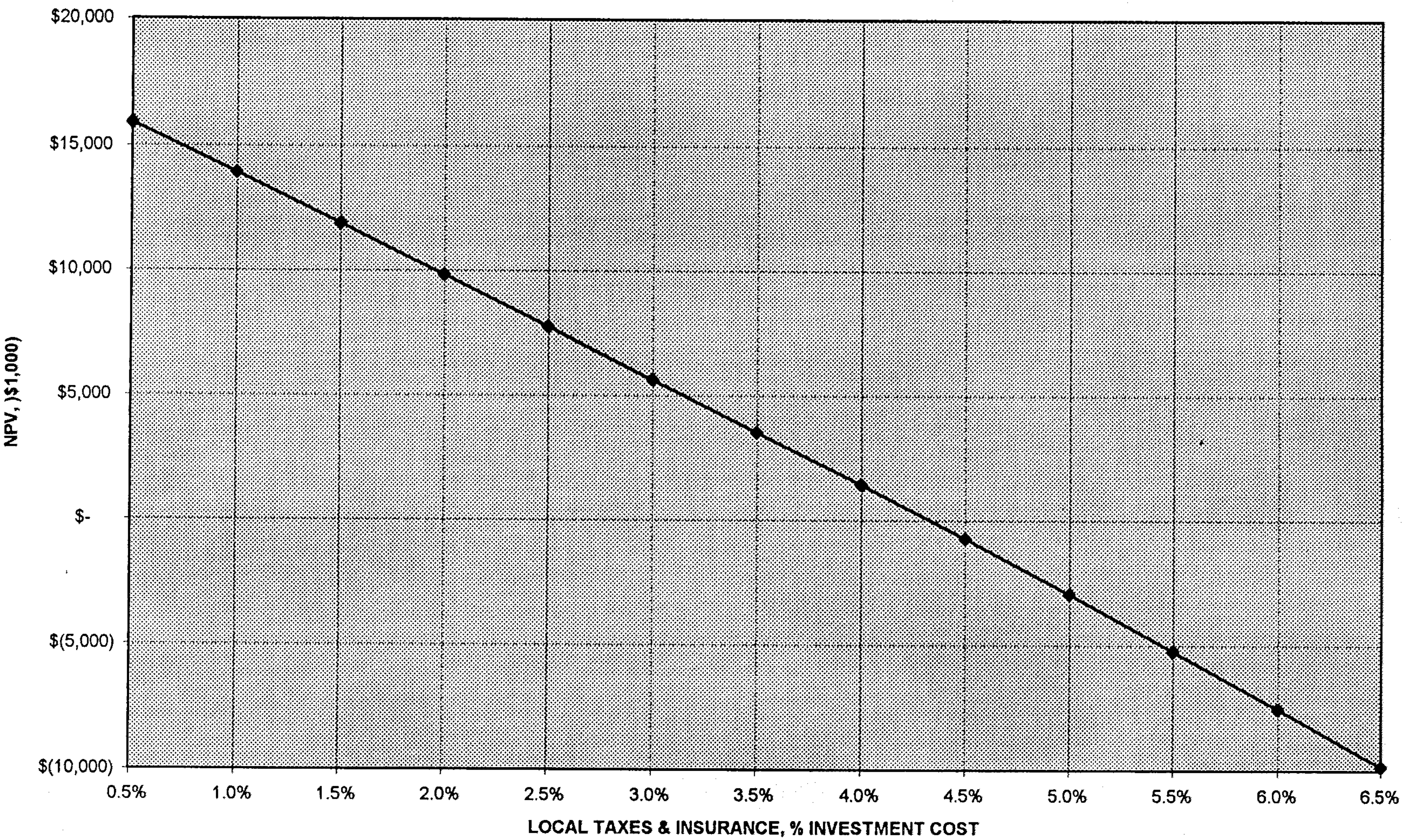


Figure 6-5A: Local Taxes & Insurance

VARIATION OF NPV WITH % DEBT FINANCING AT VARIOUS INTEREST RATES

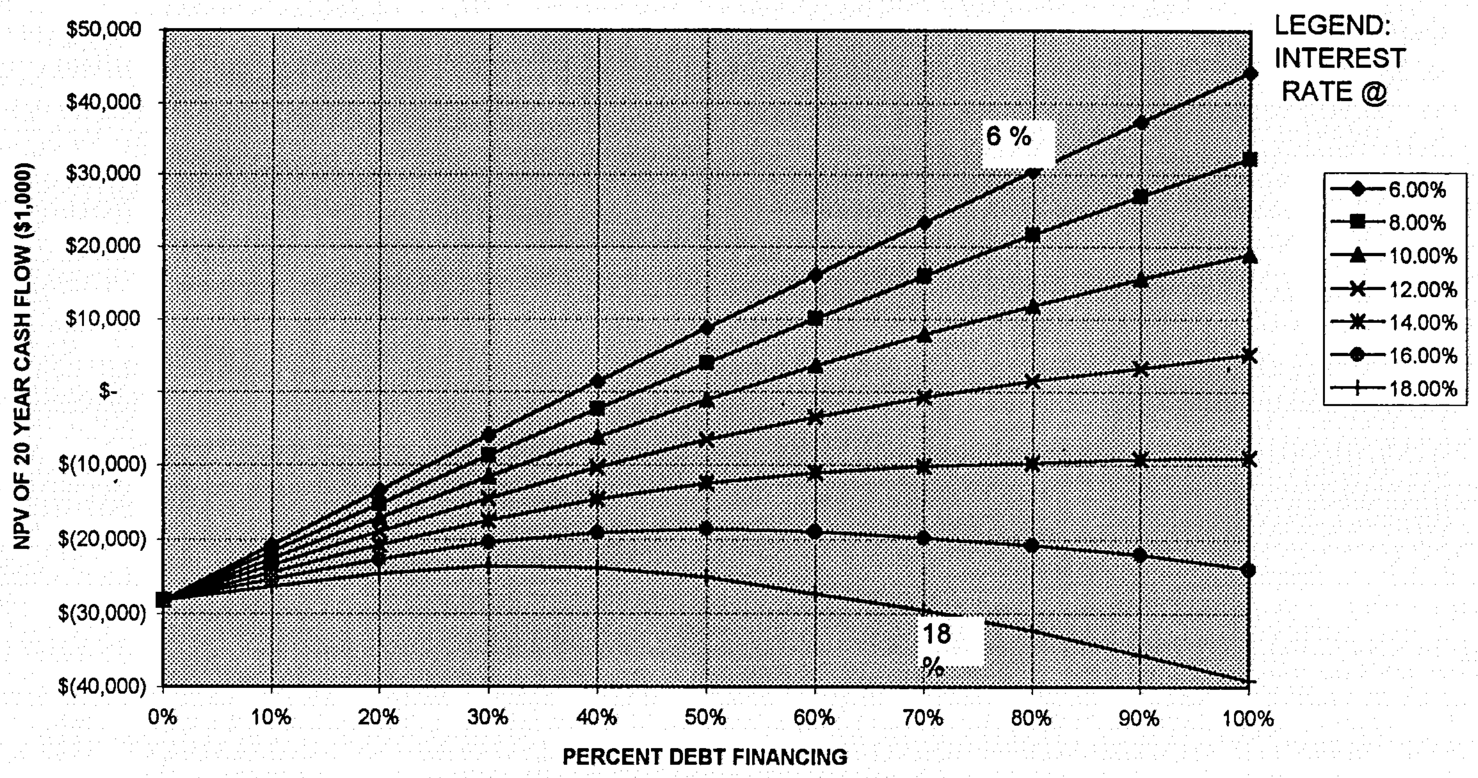
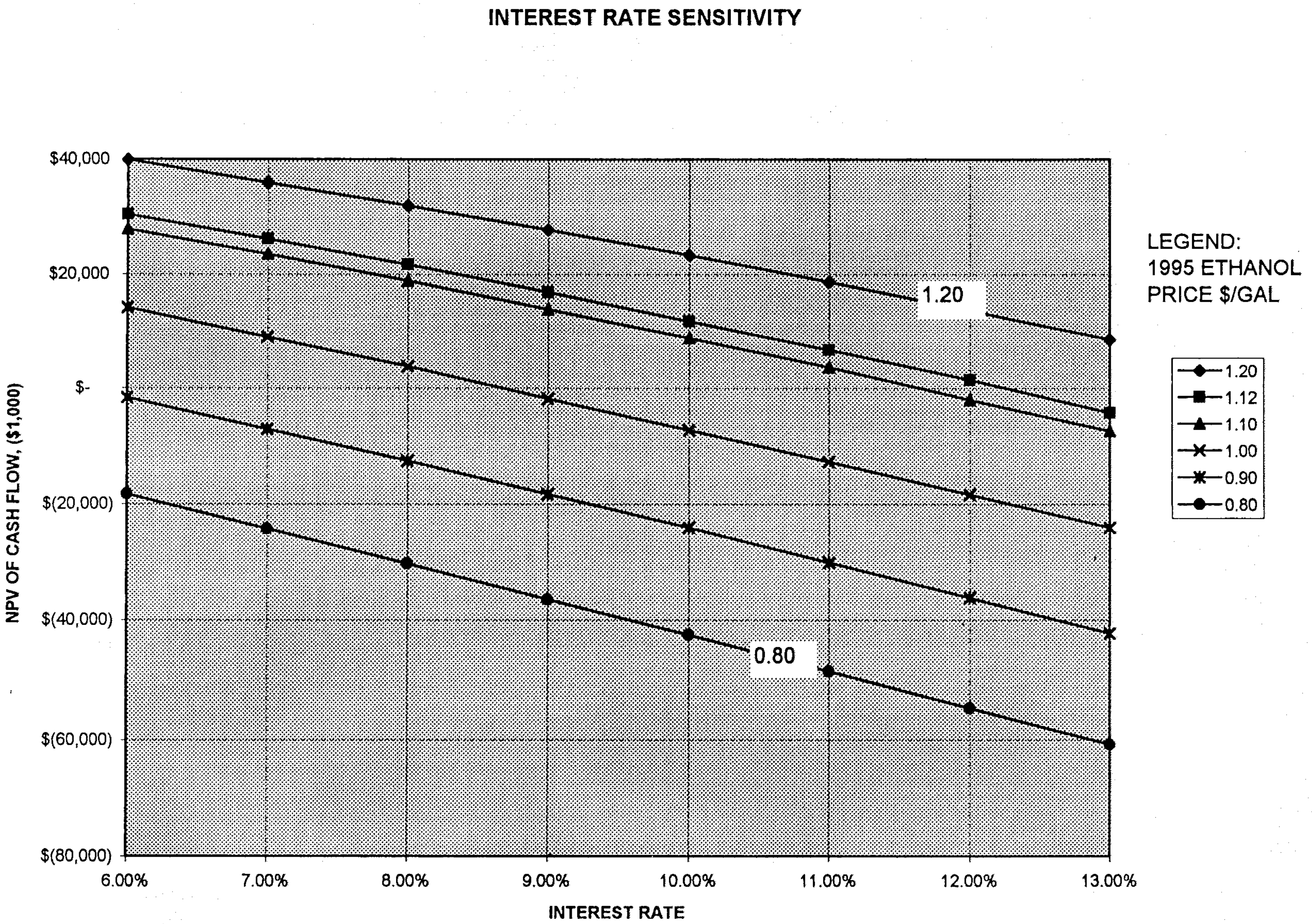


Figure 6-6A: Percent Debt



Capital INTEREST RATE

Figure 6-7A: Interest Rate

SENSITIVITY OF NPV WITH ETHANOL PRICE & PLANT COST

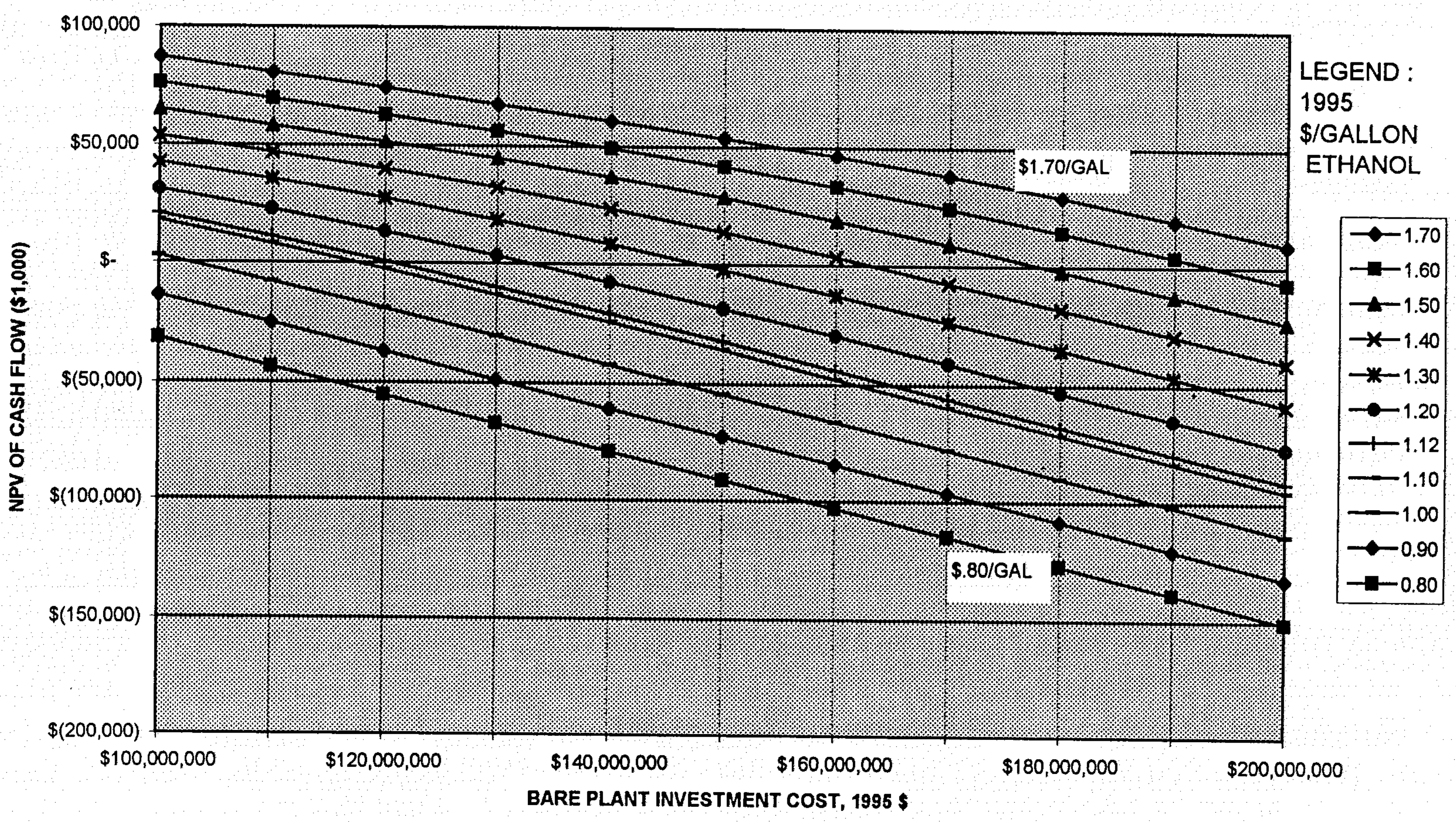


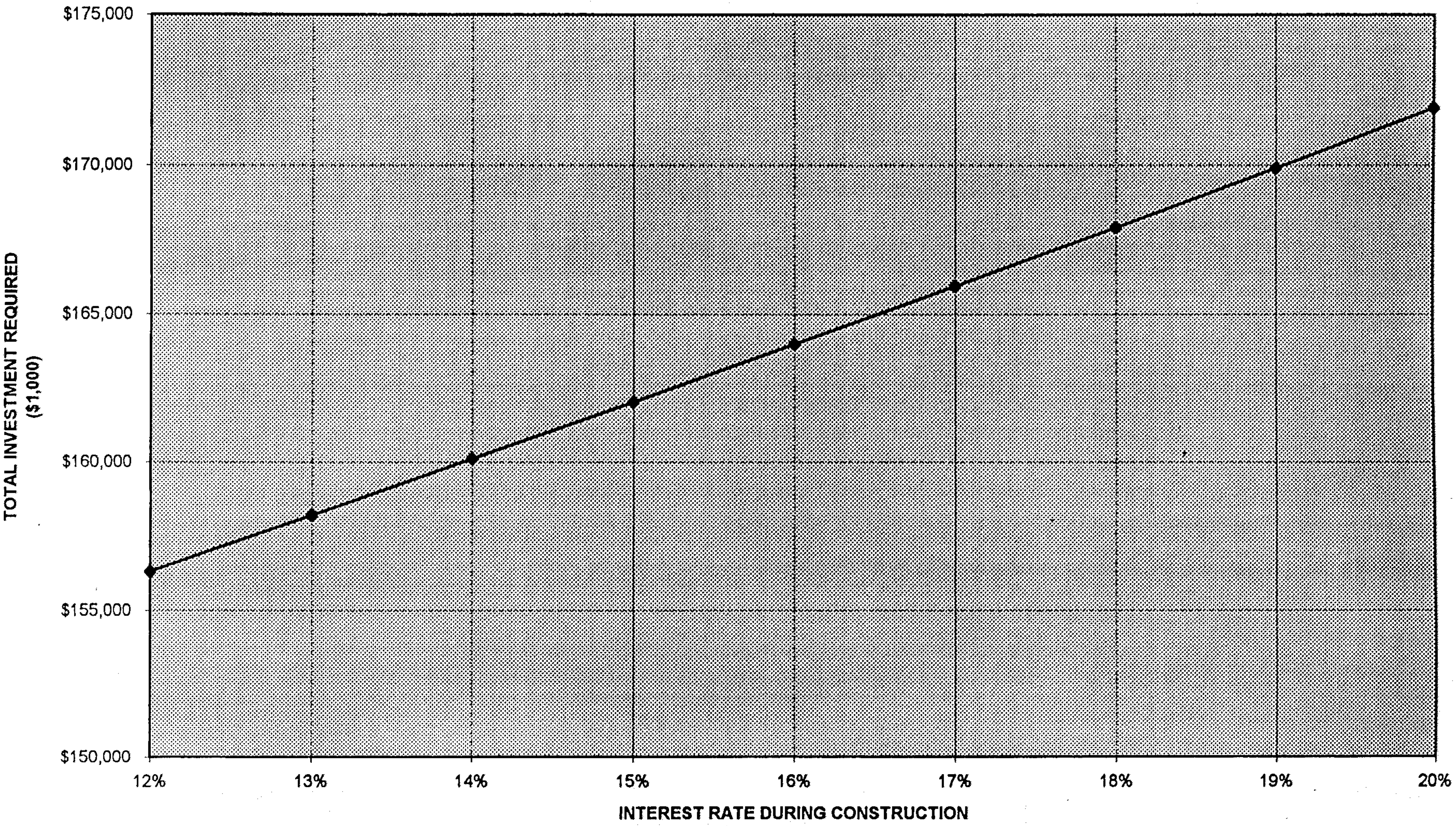
Figure 6-8A: Investment

BELCAN ENG'G
PROJECT 315-7324

NREL STUDY OF ETHANOL FROM SAWDUST
SITE - A, GREENFIELD SITE

8/11/95

TOTAL INVESTMENT REQUIRED AS A FUNCTION OF INTEREST RATE DURING CONSTRUCTION



CONSTRUCTION INTEREST

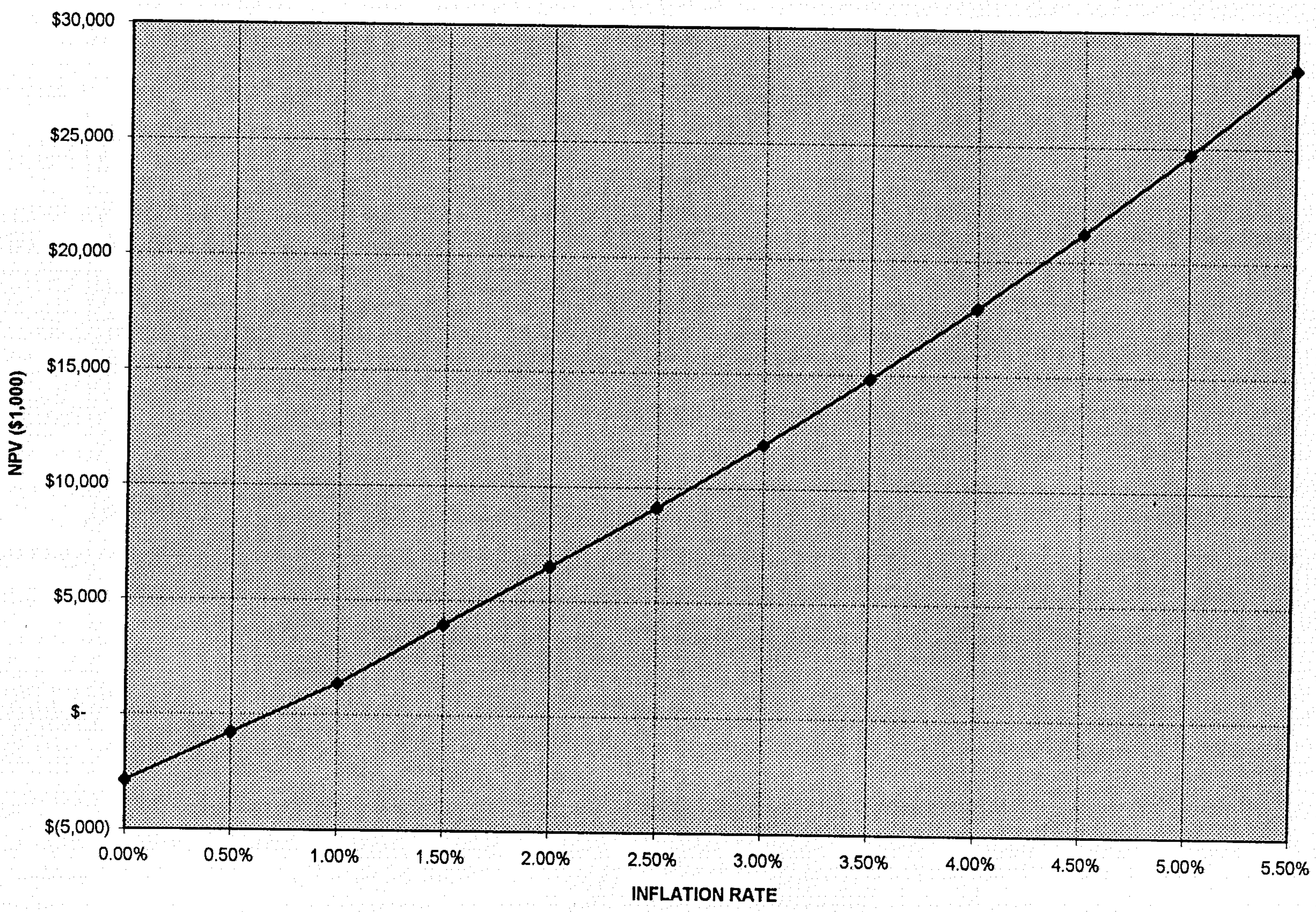
Figure 6.9A: Construction Interest

BELCAN ENG'G
PROJECT 315-7324

NREL STUDY OF ETHANOL FROM SAWDUST
SITE - A, GREENFIELD SITE

8/11/95

EFFECT OF INFLATION RATE ON NPV



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Capital INFLATION RT

Figure 6-10A: Inflation Rate

EXISTING SITE EXHIBITS TO PRO FORMA ANALYSIS